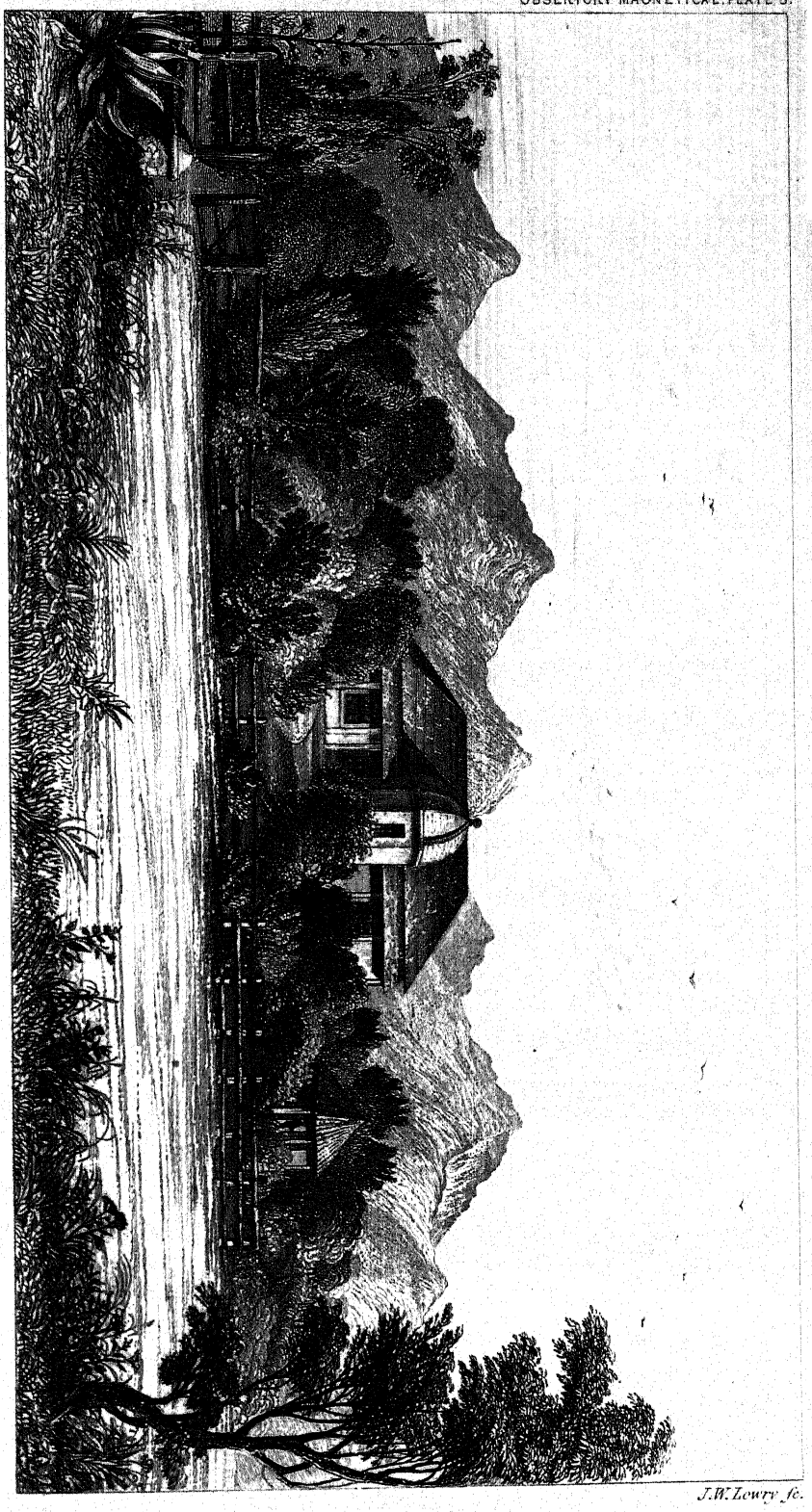


J.W. Lowry sc.

London. John Weale 59 High Holborn 1849.

Magnetical Observatory, St Helena.

AIDE-MÉMOIRE

TO

THE MILITARY SCIENCES.

FRAMED FROM

CONTRIBUTIONS OF OFFICERS AND OTHERS

CONNECTED WITH

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ORIGINALLY EDITED BY

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VOL. II.

FORTIFICATION-----PALANQUE.

WITH NUMEROUS PLATES AND WOOD-CUTS.

London:
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[*By Assignment from* JOHN WEALE, *High Holborn.*]

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NUMEROUS WOOD-CUTS.

AIDE-MEMOIRE.

F.

FORTIFICATION.

PRELIMINARY OBSERVATIONS.*

Fortification is the art both of securing a military position against surprise, and rendering it defensible by a small number of men against the attacks of a larger body. This is effected by occupying portions of the ground to be protected with works of defence, making, at the same time, every possible use of the natural obstacles and advantages which the position may afford.

Whatever may be the nature of the ground to be fortified,—whether, for instance, occupied by a dockyard, arsenal, town, or army,—certain great principles which should govern the construction of all works of defence, remain the same; the degree to which these principles can be carried out, varying with the time and means available, as well as with the skill of the superintending Officer in making the most of his resources.

These great principles are as follows:—

1st. To afford cover or protection to the defenders from the effects of every description of fire which the enemy can bring to bear.

2nd. To arrange the works so that the defenders may be able to use their weapons with the fullest effect against the enemy, from the time when he first appears within their range, up to the moment of his coming in contact with them.

3rd. To make the most of every natural obstacle in the way of the enemy's approach, and to interpose every practicable artificial one, in order that he may be constantly checked under fire; taking care, on the other hand, to remove everything which might afford him cover in his advance.

4th. To neglect no opportunity of directing the prolongation of the faces of the works on rocky or marshy sites, where the enemy would not be able to place guns to enfilade them. A due regard must be also paid to economy both of time and material.

When works are to be constructed to secure some permanently important posts, and ample time and means are available for their erection, it has been customary to designate the branch of Fortification which treats of them as "Permanent Fortification." When, on the contrary, a position requires to be held only temporarily, and time and means are comparatively restricted, the term employed is "Field or Temporary Fortification," which branch of the science will now be treated of.—C. S. H.

FIELD FORTIFICATION.

"La fortification de campagne simple dont l'exécution est ordinairement confiée a l'Officier qui est chargé de leur défense, cette première espèce de fortification doit faire l'étude des Officiers d'Infanterie."

"La fortification de campagne composée, elle ne peut être dirigée que par des Ingénieurs, et elle doit faire partie de leur service."

* By Captain C. S. Hutchinson, R. E.

The first portion alluded to above especially refers to works of the most temporary character, generally thrown up to resist an immediate attack, and executed with the Pick, Shovel, and Felling-axe, by cutting and preparing the means found on the spot. Any Officer in the service may be placed in a position to require the knowledge necessary for this purpose.

The second part includes those works which require more arrangement, the calculation of time and materials, and the means of obtaining resources within a limited distance; to which some of the principles of Permanent Fortification are applied, and which must generally be executed with considerable care, in order to last for a moderate space of time, and resist the effects of the changes of weather.

The latter part will be first treated of; and to render the remarks as concise as possible, and avoid repetition, those subjects which have been noticed in other parts of the 'Aide-Mémoire' will be expressed in capitals as, ABATTIS, BLOCKHOUSE, DAM, etc., to which reference must be made for details.

PART I.—SECTION I.*

In the following article, the usual methods of arranging works in the field to carry out the principles of defence, enumerated in the preliminary remarks, will now be explained.—

To afford protection to the defenders of a work from the effects of all kinds of fire which an enemy can bring to bear upon it, it must be first considered what weapons an enemy would usually have at his command in the field. These will consist of Artillery, very rarely heavier than 18-pounders, and seldom exceeding 12-pounders, the rifle, musket, and the rocket. Mortars being never, as a general rule, carried by armies in the field, the defenders of a field-work will not have any vertical fire to dread, and will only need protection from fire proceeding in a horizontal or nearly horizontal direction.

The most usual way of obtaining this is, to dig a ditch and throw up the earth as a parapet or breastwork between the defenders and the enemy. This parapet is sometimes constructed without reference to form, the earth being merely thrown into a heap, and called an Epaulement (see Pl. A, fig. *a*); and sometimes in one of the forms given (Pl. I. figs. 5, 6), or in Pl. A, fig. *b*, which shows the profile or transverse section of a parapet, of the ordinary construction, on level ground; the names of the different parts being as follows:—

A B, Plane of site.
K H, Slope of banquette.
H G, Tread of banquette.
C G, Interior slope.
C, Crest or interior crest of parapet.
C E, Superior slope.
E, Exterior crest.
E F, Exterior slope.
F L, Berm.
L M N O, Ditch.
L M, Escarp.
M N, Bottom of ditch.
N O, Counterscarp.
O P Q, Glacis.
O P, Interior slope of glacis.
P, Crest of glacis.
P Q, Slope of glacis.
C D, Command or vertical height of parapet above plane of site.
D U, Thickness of parapet.
C R, Relief or vertical height of the crest above a horizontal plane passing through the bottom of the escarp.
S N, Depth of ditch, or vertical depth of the bottom of the counterscarp below the Plane of Site.

* By Captain C. S. Hutchinson, R. E.

The necessary dimensions and slopes for the various lines forming the profile will now be considered.

1st. With regard to C D, the command. This must be determined with reference to the height of the men who are to stand in the interior of the work on the level A K, and to the position of the enemy outside. Assuming 6 feet as that of the former, it might be argued that, if the enemy cannot fire into the work from a higher level than C, by making C D 6 feet, the requisite protection would be afforded. This however would not be the case, as a shot always drops in its flight when approaching the end of its range, and therefore, though a man standing at K might be just protected, another standing a few yards further back would be in some degree exposed; and if the work were so formed, as to have another parapet as in Pl. A, fig. *c*, the men standing on its banquette would be completely exposed to the enemy's reverse fire. Another reason why 6 feet is an inefficient command for a parapet on level ground is, that C, the interior crest, being a sharp angle, is very liable to be injured; and it would be very inexpedient to make a new work, such that a heavy storm, or the first few rounds of shot, might expose a considerable portion of its interior.

If the enemy can occupy any neighbouring heights which command the ground to be occupied by the work, the parapet in this case must be considerably raised, as appears evident by referring to fig. *c*. It is not considered advisable, for reasons that will be mentioned hereafter, to raise the parapets of field-works to a greater height than 12 feet; and from 7 feet to 12 feet may be therefore considered as the ordinary limits within which the command of field-works should be kept. In cases where very rapid cover is wanted, a parapet may be constructed with a command of only 5 feet; protection being obtained by sinking a trench behind the banquette, to the depth of 1 foot 6 inches, or 2 feet.—Of course the interior of the work, excepting the trench, is in this case exposed (see Pl. A, fig. *d*). Works on the summits of hills higher than any surrounding ground within range, may also be constructed with lower parapets than 7 feet, without danger of the interior being exposed.

2nd. As regards the thickness of the parapet D U (Fig. *b*, Pl. A), this depends for its minimum upon the nature of the projectile the enemy may have it in his power to bring to bear upon the work, and should be so regulated that the ball may not be able to penetrate more than about two-thirds of it. The penetration of projectiles into dug-up well-rammed earth is as follows:—

Weapon.	*Penetration.*
Musket	1 foot 6 inches.
6-pounder	3 feet 6 inches to 4 feet 6 inches.
9-pounder	6 „ 6 „ 7 „ 6 „
12-pounder	8 „ 6 „ 10 „ 0 „
18 and 24-pounders	11 „ 6 „ 13 „ 0 „

The minimum thicknesses would therefore be about as follows:—

Weapon.	*Minimum thickness for security.*
Musket	3 feet.
6-pounder	6 „
9-pounder	9 „
12-pounder	14 „
18 and 24-pounders	18 „

These dimensions apply to earth of an ordinary tenacity. With light sandy or gravelly soil, a greater minimum thickness ought to be allowed.

If more time and labour are available than requisite to form a parapet of the mi-

nimum thickness required, there can be no reason, provided the position admits of it, for not materially increasing this thickness; as a wider or deeper ditch may thereby be procured.

The superior slope C E is usually made from $\frac{1}{6}$ to $\frac{1}{4}$ (*i.e.* C T = $\frac{1}{6}$ to $\frac{1}{4}$ T E). It should be so directed that the fire of the parapet may be delivered about 2 feet above O if there be no glacis, or 2 feet above P if there be one. It should be kept as gentle as possible, consistent with these conditions, to avoid weakening more than absolutely necessary the crest C.

The exterior slope E F is left to assume that natural to excavated earth; averaging 45°.

The interior slope C G or C G′ is made steep, usually with a base of about a quarter its height, to enable the soldier to get close to the crest in firing. To retain it at this slope it will require revetting. This may be done with sods, fascines, gabions, sand-bags, hurdles, casks, planks, &c., as may be most readily procurable.

To obtain musketry fire from the parapet (that of artillery will be explained further on), the banquette or foot-bank K H G is raised up. Its depth below the crest is arranged so as to enable a short man to fire down the superior slope with facility, and therefore depends upon the steepness of this slope as well as on that of the interior slope.

For a superior slope of $\frac{1}{6}$, and interior slope of $\frac{4}{1}$, the depth may be assumed at 4′ 3″,—becoming less as the steepness of the former increases and that of the latter diminishes. The width of the tread H G is made $4\frac{1}{2}$ feet or 3 feet, according as it may be necessary to arrange for a double or single rank of men occupying it at the same time. It should have a slope to the rear of 1 inch or $1\frac{1}{2}$ inch to the foot, to keep it dry.

The slope of the banquette H K is made gentle, about $\frac{1}{2}$, to enable the men to descend and ascend with facility before and after loading. In case the command of the parapet is considerable, steps should be substituted for the slope, whereby less interior space will be taken up. These steps may have a rise of 9 inches to 1 foot, and a tread of 1 foot to 1 foot 6 inches, with a slight slope to the rear. It is often desirable, where the interior space is considerable, and command great, to leave a second banquette between the first one and the ground, about 7 feet below the crest, upon which the men may load (see Pl. A, fig. *e*).

Passing now to the exterior of the parapet the berm F L occurs. This space is necessary to prevent the pressure of the parapet from breaking down the escarp (if unrevetted), and to stop any earth which might escape from the superior or exterior slopes from falling into the ditch. It also facilitates the construction of the work, by affording a space upon which the earth from the ditch may be thrown, when the latter becomes too deep or wide to permit of the soil being delivered, where required, at one throw. The berm is otherwise an evil, as it gives an opportunity to an escalading force to halt and form before rushing up the exterior slope: on this account it is made as small as possible, viz. from 1 foot to 3 feet; the latter dimension being used only in case the soil is very loose. In small parapets, where the soil is tenacious, the berm may be dispensed with altogether. It is generally left on the natural level of the ground, unless the command of the parapet is less than 6 feet, in which case it must be kept about 6 feet below a plane passing through the crest of the work, and parallel to its plane of site.

The form and dimensions of the Ditches of Field-works will now be considered, it being borne in mind that the ditch has to serve a double object, viz. to offer a real obstacle to an advancing enemy, and to furnish the earth requisite for the formation of the parapet.

1st. With regard to depth: as a general rule, this should not be less than 6 feet, nor more than 12 feet. If less than 6 feet, hardly any obstacle would be afforded by the ditch to an advancing enemy. If more than 12 feet, the labour of excavation becomes very great unless machinery is introduced, and this would be seldom available in the field; and the slopes of the escarp and counterscarp (unless in exceedingly stiff soils) would not be found to stand for any length of time without the introduction of some artificial revetment, such as planking, hurdles, &c., a supply of which would not be usually attainable.

2nd. With regard to breadth: this should not, if possible, be less than 9 or 10 feet at the top, to prevent it being easily jumped across or bridged over.

The slopes of the escarp and counterscarp must be determined with reference to the tenacity of the soil, the length of time for which the work will probably be required, and whether during this time it is likely to be exposed to heavy rains and sharp frosts. The counterscarp may be left steeper than the escarp from not having the pressure of the parapet to support, and also from not being exposed to the enemy's fire. The slope of the escarp may vary from $\frac{1}{1}$ to $\frac{2}{1}$; that of the counterscarp from $\frac{1}{1}$ to $\frac{3}{1}$.

To obtain the size of the ditch, such that it may supply the requisite earth for the parapet, the area of the profile of the latter must be calculated, it having been first constructed to fulfil the requisite conditions. Let A = the area thus obtained, d = depth of ditch, w = width at top, $\frac{d}{e}$ = base of slope of escarp, $\frac{d}{c}$ = base of slope of counterscarp, then

$$d \times \left(w - \frac{d}{2e} - \frac{d}{2c}\right) = \text{A}.$$

Either d or w may then be assumed, within the limits above mentioned, and w or d obtained. If by the value assigned to d, even if made equal to its minimum, 6 feet, w becomes less than 9 feet (a case that would generally occur in works of small command, constructed as in fig. *d*, where a portion of the parapet is formed by the earth from the rear trench), the escarp and counterscarp should be brought to meet in a point, and the equation will then become

$$d\left(\frac{d}{2e} + \frac{d}{2c}\right) = \text{A},$$

A being now the excess in area of the profile of the parapet over that of the rear trench.

In calculating as above, no regard has been had to the increased bulk which all earth, when excavated, unless excessively well rammed, will occupy; nor is it in general necessary to do so, seeing that the excess will generally be disposable for the formation of traverses and barbettes. It must be also remembered that the form of the work on plan has not been taken into account; it being evident that wherever a salient angle occurs, there will be a surplus of earth, and a deficiency at a re-entering angle. This may be met in practice by diminishing or increasing the depth or width of the ditch, at those points where the excess or deficiency is met with.*

A glacis O P Q becomes necessary when the prolongation of the superior slope C E

* The equation which expresses strictly the relation between the volume of the parapet and that of the ditch is as follows:—Let A = area of profile of parapet, D = that of ditch, $\frac{1}{m}$ = increase of volume of the excavated earth, g = length of path of centre of gravity generated by the motion of the parapet along the interior crest, g' = the same line with reference to profile of ditch, then (by Guldinus's property of the centre of gravity)

$$g \times \text{A} = g'\left(\text{D} + \frac{\text{D}}{m}\right),$$

g', A, and m, being known, and the width of the ditch assumed, g may be measured and the depth obtained.

falls more than 2 or 3 feet above O, and when consequently an enemy arriving at this point, where he receives a check in his advance, would, without a glacis, be almost under cover from the direct fire of the work. The command P V of the glacis must therefore be such as to admit of the fire of the parapet passing 2 or 3 feet above P, care being at the same time taken to keep the point P at least 6 feet below a plane passing through C and parallel to the plane of site of the work, so that its interior may not be commanded from the crest of the glacis. The interior slope O P is left at the natural slope of the earth 45°; the slope P Q may have the same inclination as the superior slope of the parapet, or a more gentle one. In case of a glacis being employed, the area of its profile must be added to that of the profile of the parapet, to obtain the corresponding area of the profile of the ditch.

Having thus discussed the normal conditions which should be attended to in the formation of the profiles of field-works, the general principles which govern their trace will now be considered, premising these remarks (as in those on profiles) by some definitions.

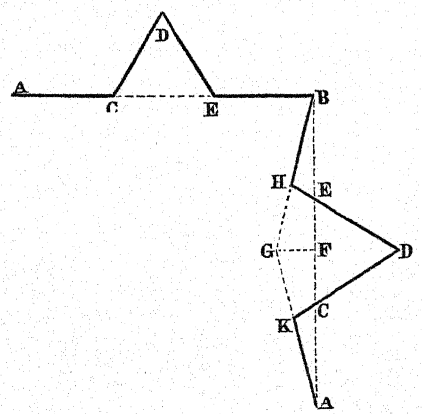
Plate A, fig. f.—H G A C E, F D B K L, represents the trace of the interior crest of part of a bastioned fort (this trace being employed as embodying most of the terms in general use).

A G, A C, Faces of the bastion.
G H, C E, Flanks.
E F, Curtain.
H G A C E, Bastion.
A C E F D B, Bastioned front.
M N O, Ravelin.
G A C, Salient angle.
C E F, Re-entering angle (and in this case angle of the flank).
A F D, Angle of defence.
A C E, Angle of the shoulder.
A B, Exterior side of the polygon.
P Q, Interior side of the polygon.
R S, Perpendicular.
A F, Line of defence.

C. S. H.

SECTION II.

The common mode of constructing a bastioned front is to make R S = $\frac{1}{5}$, $\frac{1}{7}$, or $\frac{1}{9}$ of A B, according as the polygon is a square, pentagon, or greater polygon; join A S, B S; make A C and D B each = $\frac{2}{7}$ or $\frac{1}{3}$ A B; draw C E, D F, at right angles to B E and A F respectively, and join E F (Plate *A*, fig. *f*).



For a demibastion the outline would be A F D B or B E C A, the construction being otherwise the same (fig. *f*).

For the Star fort,* the side A B of a triangle or superior polygon is trisected, and an equilateral triangle C D E is described on the centre division; or, to obtain more direct flanking fire, in polygons greater than the triangle, the side is also bisected, a perpendicular, F G, dropped as for a bastioned front, and D C, D E, produced to K and H, the front being A K D H B.

C. R. B.

* Great objections exist to this form (see p. 22).

SECTION III.—GENERAL PRINCIPLES.*

a. The extent should be in proportion to the number of men assigned to the defence.

b. The approaches should be well seen, and, if possible, taken in flank (see fig. 63, Pl. IX.); and all obstacles forming part of the defence should be within 200 yards, for musketry fire,† and 500 for field-pieces.

c. The salients, when possible, should be thrown into inaccessible hollows, marshes, or rivers, if not flanked by a cross-fire, as explained in paragraph *b*.

d. Flank defence for the security of the ditch is rarely applicable to this description of field fortification, for want of depth of profile or sufficient relief to secure those men who line the parapets from destruction from the fire of the collateral flanks, or works, if detached: hence all auxiliary protection, as PALISADES, ABATTIS, or CHEVAUX DE FRISE (see Plates VIII. and XIV. figs. 54, 55, 94, and 95) should be seen from the parapet of the work they are intended to protect, and consequently ditches should be considered as the *déblai* only, or means of furnishing the requisite quantity of earth for the parapets, banquette, and glacis.

e. Hence the ditch of a field-work is no security and rarely much obstacle.

f. Musketry or rifle fire is the legitimate defence; and the point to be gained is to keep the attacking force under it, either from front or flank; a detention of a few minutes being sufficient in most cases.

g. Artillery seldom forms part of the defence of this description of field fortification; the work is generally to cover and secure the artillery, principally from cavalry; the field-pieces being planted for some especial purpose, as in fig. 63 (see also 'BATTERY,' Sect. XIII.).

h. Field-works seldom stand alone; they generally form a system of defence, supported by troops; when isolated, they should be constructed with care.

k. All field-works should be fortified outwardly, making the interior slope of the parapet the trace of the work; otherwise the area within will be frequently found too confined.

l. The available interior space should not be less than 20 square feet per man, within the banquette, and 220 square feet for each field-piece.‡

m. Time, though not of primary importance, is essential to the professional Officer, to avoid attempting beyond his means, and the object of the works to be constructed.

n. In the execution of a work, sufficient command should be given to the profile; so that an enemy outside, on the crest of the ditch or glacis, should not see into the works.§

o. With the above precautions and those given in page 1, the shape of the work is of no consequence, provided it is adapted to the ground, object in view, and time necessary in construction; and the several diagrams are given in Plates IX. to XIII. to assist the Officer in the hurried moments of execution.

SECTION IV.—DESCRIPTION OF FIELD-WORKS.

e IX.

a. Redans.—Figs. 64, 65, and 68, serve for the security of advanced posts, or couvre-portes to works and buildings, and they are sometimes termed flèches; when

---

* By Major-General Lewis, C.B., R.E.

† The range of the modern rifle may be taken as equal to that of field-pieces.—ED.

‡ See page 27, on 'GARRISONS.'

§ See also page 3, for further reasons.

they have flanks, as in fig. 64, they are called lunettes: these works are only used when supported by others.

b. Redoubts are enclosed works, without flank defence: when constructed with flanks, they are called forts. Redoubts, as in fig. 64, 67, 68, and 69, may be either square, circular, or polygonal.

c. Square Redoubts should not have their interior side less than 60 feet; but if less than 100, there is not sufficient space for a reserve for the defence. A BLOCK-HOUSE, or DEFENSIBLE GUARDHOUSE, is the best support to a square, with the sides placed opposite the salients, as in fig. 67. In connection with other works they are frequently arranged as in fig. 64.

Plate X.

d. Circular Redoubts are rarely constructed, but fig. 68 is a notable example of their utility, taken from a French work on the banks of the Zezere River, in Portugal.

e. Polygonal Redoubts are most convenient for enclosed works without flank defences, as they can be suited to the contour of the ground, and they afford more interior space: fig. 69 is an example, with an inner work to serve as a keep.

f. Field Forts consist of star forts, bastion forts, and polygonal, with re-entering angles *en tenaille*.

g. Star Forts.—The construction of these involves much trouble, and they are rarely applicable to temporary works: when used, they should not be constructed upon a polygon whose sides are less than 100 feet or more than 200 feet. These works are especially adapted to isolated spots (see fig. 66).*

h. Bastion Forts are not well calculated for field-works, and, when constructed, the flanks should have at least an opening of 100° with the line of defence. They are best applied as TETE-DU-PONT, for the construction of bastion forts is difficult; requiring exterior revetments, there is loss of space, and they are not easily adapted to the ground.

i. Polygonal Forts will be found applicable in preference to any nicely constructed work analogous to Permanent Works. Polygonal forts are generally suited to the ground (see figs. 70 to 73, and 84). Fig. 71 is a trace of a work constructed and defended by the British troops in 1794, the capture of which led to the evacuation of Toulon.

Plates VI. and IX.

k. Epaulements for cavalry and connecting other works, as in fig. 64, are constructed in open plains, where there is no irregularity of ground to cover cavalry, to protect them from a cannonade, as explained in figs. 43 and 44: to the latter is a banquette for musketry, converting the epaulement into a detached curtain.†

SECTION V.—OBSTACLES AND AUXILIARIES OF DEFENCE,

such as ABATTIS, BARRIERS, BLOCKHOUSES, CHEVAUX-DE-FRISES, DAMS, FOUGASSES, FRAISES, PALISADES, STOCKADES, and TROUS-DE-LOUP, are treated of under their several heads in the 'Aide-Mémoire:' these are artificial; there are many natural resources besides, such as inundations (see Article 'DAM'), marshes, and precipitous ground, the latter of which may be improved by scarping the face, and slopes, and by means of QUARRYING (see fig. 90, as applicable to the security of the front and flanks of field-works), and may be termed local; whilst the artificial obstructions, or auxiliaries of defence, must depend upon the nature of the means within a moderate distance.

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* For construction of Star and Bastioned Forts see page 6.

† Further observations with reference to LINES, or combined Field-works, will be found under that head.—ED.

SECTION VI.—TIME REQUIRED TO EXECUTE FIELD-WORKS, DISTRIBUTION OF THE WORKMEN, AND NUMBER OF MEN NECESSARY FOR THE DEFENCE, AS APPLICABLE TO PART I.

a. Time required.—Find the number of cubic yards in the ditch or ground to be excavated, and divide the amount by the number of shovels to be employed, which will give the number of hours,—the nature of the soil giving the number of shovels required. For the sandy soils, three-fourths will require shovels; in clay, two-thirds; and in hard gravelly soil, one-third of shovels is necessary in the excavation. A reserve of tools should always be provided in the event of the ground changing after the surface is removed, but with a crow-bar the soil may be pretty accurately ascertained.

b. Distribution of Workmen.—Divide the length in feet of the centre of the ditch of a given work by 4, and it will leave the number of workmen to be employed in the first row, and half that number for the second row; and the first number again to adjust the earth and revet the parapet: if the ditch is narrow, only one row will be requisite.

Example: Suppose the ditch is 120 feet, which divide by 4,—gives

30 for the first row,
15 for the second,
30 for the parapets,
—
75 total number of men to be employed.

c. Number of Men for the Defence of a Work.—First, if open, or supported by collateral works, give 2 men for each linear yard of interior of parapet. Secondly, if isolated, give 2 men + $\frac{1}{3}$ for a reserve, provided the work has not less than 160 yards of parapet.* If isolated, and of less capacity, it is presumed that it can only be partially attacked.†

The men for defence should have the front rank placed on the banquette, and the second behind on the terreplein of the work, to load: if the men are allowed to step up on the banquette and fire, they will do so at random.

SECTION VII.—TRACE, PROFILE, AND CONSTRUCTION OF FIELD-WORKS.

a. Trace.—Previous to this operation, it will be found convenient, and eventually a saving of time, if the project of defence is put on paper by the Engineer, and submitted to the Officer commanding the troops, to obtain his signature, if approved; for works treated of in this Part of Field Fortification should be duly considered. This preliminary being settled, and the tools collected, the following articles will be necessary for tracing the work:—

Hambro' lines.	Bevels adapted to the slopes of parapets.
Pickets, 18″ long.	A straight-edge.
Mallets.	Two short lengths of scaling ladders.
10-feet rods.	Profile stuff.
Mason's levels and bob.	

The last should be made from 3-inch deals, cut across into battens 1″ × 3″, and a certain quantity into poles 3 inches square for uprights.

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* According to Sir John Jones, this was found to give too large a garrison (see page 27).

† If guns are used, about five yards should be deducted for each from the length of the parapet, *before* calculating the number of men; if at an angle, double that amount.—ED.

Thus provided, the works should be traced out, as explained in Article 'BATTERY,' with the Hambro' line stretched upon that corresponding with the entire crest of the parapet (*o*) in the annexed diagram; and from this the dimensions marked out by pickets firmly driven into the ground, transferring the works from the plan approved; when probably some modification will be found necessary, when the tracing is completed, by marking it on the ground with a sharp spade, called spit-locking.

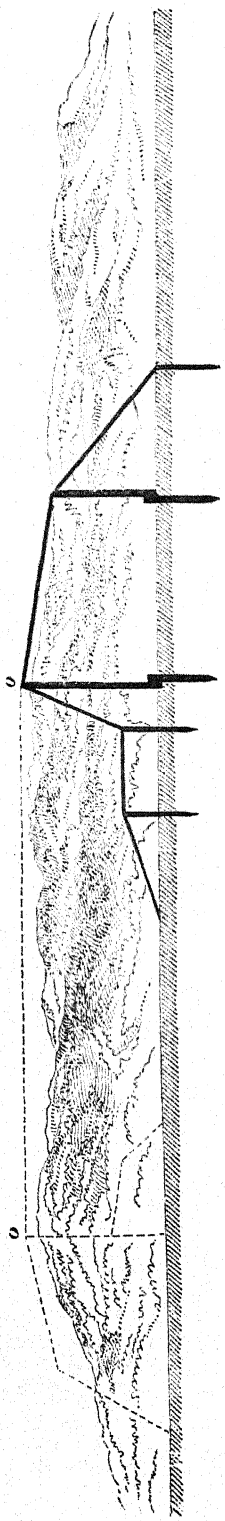
b. Profile.—The question of relief having been decided upon in reference to command, or DEFILADE, or as a security against artillery, or only against musketry, the dimensions will be found in figs. 45 to 53:* the poles must be driven into the ground, corresponding with the angles of the work, and the battens nailed to them, as explained in the diagram.

Plate VII.

The under surface of the battens give the dimensions of the work, by which means the uprights only will be lost, and buried in the ground. And in order to judge whether the interior of the work is sufficiently covered from without, or defiladed, if in the vicinity of high ground, a cord should be stretched from profile to profile, *o* to *o*; (see the diagram, corresponding with the crest of the parapet.)

c. Construction and Execution of Field-Works.—The *remblai* and *déblai* having been calculated from one of the profiles chosen in the figures of the Plates on Field Fortification, the materials taken from the ditch should be so placed that the work may be raised to the whole breadth of the parapet and banquette and of rampart, and should be carried up in even courses of about 18 inches or 2 feet, and well consolidated with the earth-rammers to the level of the banquette, when arrangements must be made for revetting the parapet.

d. Revetments of Field-Works.—These are generally necessary to the interior slope of the parapet, and sometimes to the exterior, to give the necessary solidity, and prevent it crumbling away by the effects of the weather, otherwise the parapets would lose their proper dimensions. The interior slope may be lined with FASCINES, GABIONS, or HURDLES, as likewise the cheeks of the embrasures, but artillery in these works are generally *en barbette*, or as is explained in Article 'BATTERY,' Section XIII. There are resources to be found on the spot occasionally, such as *sods*, also *old building-stones* and *bricks*: the latter could be built up within 2 feet of the crest of the parapet, and then completed with sand-bags or sods, or earth well beaten. Sun-burnt bricks will serve in some climates, and last many



Profile of Field-Works.

* See also pages 3, 4.

years. When the exterior slopes of the parapet require to be revetted, the *branches* and *trunks of trees* will serve, laid horizontally, as also *logs of wood* squared or unhewn, trenelled together, where timber is abundant.

SECTION VIII.—GATES OR BARRIERS, DRAINING AND COMMUNICATIONS.

a. The *entrance* should be always well traversed and palisaded, and secured with gates or BARRIERS, as explained in the latter Article.

b. The *draining* and keeping the works clear of water is an essential consideration in the construction of this description of Field Fortification, to preserve them for a certain time, so as to drain the ditches as well as the interior of the work; and for a good method of doing so, see Article 'DRAIN.' The interior of the work should be also levelled and dressed towards the several drains.

c. The *roads* and *communications*, although last mentioned, should be at an early period attended to, as facilitating the several operations in the construction of works. The formation of ROADS must also have reference to whether required as the means of communication for the troops and artillery, or as connecting the works by a covered passage, where the earth will be thrown up outwardly as a parapet or glacis, always leaving the interior slopes sufficiently gentle to allow the infantry and cavalry to advance or retreat over them (see Pl. XIV. fig. 96).

SECTION IX.—CONCLUSION TO PART I.

The division of Field Fortification, of which the works are supposed to be designed and executed by an Engineer or Staff Officer, is written to remind him on the spot, ready for action, and not as an Essay on Fortification, which would exceed the object of the 'Aide-Mémoire,' and also to give the general principles, leaving the proper application to the ground and circumstances to the person entrusted with this important charge—having in consideration always one point, to observe if there is not some principal feature to serve for the key to the post or position, and which, if fortified with care and skill, may make it difficult, and sometimes impossible to overcome; such as a flèche or redoubt, with artillery placed in a marsh, or on a summit of a precipitous ground, or covered by an impenetrable wood, which may take in reverse the advance, or flank the approaches to the post or position.

PART II.*—SECTION I.

a. The following description of tools and stores would be found more or less necessary, where *temporary works* are to be thrown up, and they should be furnished in the required proportions to any detachment whose duty it might be to strengthen and afterwards defend a post.

b. They are classed in three divisions, that their separate uses may be apparent.

Class 1. Field Service Tools.

Shovels Pickaxes Felling-axes Bill-hooks	For sinking trenches, forming breastworks, felling timber, making abattis and obstructions, etc.

Class 2. For Houses, Walls, etc.

Sledge-hammers Hand-borers Crow-bars Saws Augers Spike-nails	For forming loopholes, breaking through walls, preparing timber for barricades, stockade-work, etc.

* By Lieutenant-Colonel Jebb, R.E.

Class 3. General Service and purposes of Defence.

Sand-bags Rockets Small shells Hand-grenades	The sand-bags for blocking up windows, and forming loopholes, etc. The rockets and shells for defence of houses and intrenchments.

c. The proportions of these necessary to be demanded will of course vary with the description of work which may be anticipated.

For example, in throwing up earthen-works in an open country, a pickaxe and shovel for every man that could be employed on the breastworks would be wanted. If an ABATTIS could be formed, and there were fences to be cut up and levelled, one-third of the men would be advantageously employed with felling-axes and bill-hooks. In a case where houses were to be placed in a state of defence, walls would have to be broken through for making loopholes, and windows, doors, and passage to be barricaded: here crow-bars, hand-borers, sledge-hammers, spike-nails, and saws, would be required in greater proportion than spades and pickaxes.

Sand-bags are included as being very useful for many purposes, such as protecting men when firing over a parapet or breastwork; quickly blocking up the lower parts of windows, etc.; in each case, loopholes being arranged by disposing them as shown in fig. 31.

A man will carry one hundred empty sand-bags, weighing about 60 lbs., each of which will contain a bushel of earth, and when *full* will be *musket-proof*.

Rockets,* small shells, and grenades, are mentioned as being very powerful and attainable auxiliaries in the defence of posts and houses; and one great advantage of them is, that anybody who has common sense may use them, or at least be instructed in the requisite precautions in a few minutes.

d. A certain *division of labour* must also be attended to, and a man should always have a tool put into his hand that he has been accustomed to use: carpenters should therefore be employed where saws and axes are wanted; miners and black-smiths where walls are to be broken through: labourers where the spade and pickaxe come into play. Those who never handled tools of these descriptions would be most usefully employed in collecting materials. It would be well also to select such men for the first tour of duty, as patrols and sentries, and to employ the best workmen in overcoming the greatest difficulties, which are usually found in the commencement. A little foresight will not be misapplied in considering these points.

e. It is useful to obtain the assistance of the inhabitants in executing works of this description, and an Officer should always have authority to enforce their attendance, and to pay them in proportion to their exertions. They should also be required to bring with them whatever tools they can best use, or that are most wanted.

SECTION II.—BREASTWORKS.

a. A general idea may be formed of the quantity of work that can be done in a given time, and of the proportion of cover that may be obtained in that time, by

* As an illustration of the use of rockets, it may be mentioned that on one occasion, during the late war in Canada, an American gun-boat took up a position which enfiladed a situation where a bridge that had been destroyed was being re-established; from whence she kept up a fire that bid fair to stop proceedings. Artillery could not be brought up, but luckily rockets were thought of, and a few were obtained from the rear. The second that was fired entered her bows, and caused so many casualties, that the 24-pounder was reduced to silence; and it was only by a shift of wind that the boat was got off, after being driven close in shore, and many of the remaining men being killed or wounded by a light company that ran into the water up to their pouches, in the hope of taking her.

adopting different sections when throwing up the earth, by referring to Plates I. and II. figures 1 to 7, and the corresponding estimates, which are calculated on the following data:—

First. That on an average, an ordinary labourer will dig out *one cubic yard* or *twenty-seven cubic feet of earth an hour*, in middling soil; and continue to work at that rate for eight hours or more. And secondly, on the supposition that EACH MAN HAS SIX FEET IN LENGTH TO EXECUTE, which distance enables him, when at work with others in a line, to use his tools with perfect freedom.

It should be observed, that the first of these data admits of considerable latitude, and A CUBIC YARD AN HOUR, which is a convenient average to remember, is the least work that ought to be expected, unless in a very strong hard soil: in a light sand not requiring much use of the pickaxe, an indifferent labourer would remove two cubic yards an hour with more facility than he would one in difficult soil; and, bearing this in mind, the nature of the soil on which a military post might be situated would frequently have a great influence in modifying the details. With regard to the supposed DISTANCE OF SIX FEET FOR EACH PORTION, it is not to be considered *invariable*, but *convenient*. Men may be set to work as near as 4 feet from each other, but the time gained is not in proportion to the diminished distance, for they will be too crowded to work with ease, and they will be liable to injure each other, especially at night. Still, however, there is no doubt that any given quantity of work would be completed in less time by disposing workmen at 4 or 4½ feet than at a greater distance. On the other hand, when only improving the natural advantages offered by banks, fences, etc., the working parties might be distributed at much wider intervals than 6 feet; having reference to the time in which they could execute any given portion. For instance, a man might possibly convert 20 or 30 feet of a hedge into a good breastwork in three hours, when he could not execute 6 feet in length, of one equally defensible, in the same time, that required to be artificially created on a level field.

b. Before entering further into the details, it may be right to mention as a general rule, that in almost all cases where trenches are required, it is essential that the means of getting out of them with facility, both to the front and rear, should be preserved by leaving slopes or steps for that purpose. Thus on some occasions it is desirable they should offer no impediment to a forward or a retrograde movement, but that troops should be able to march straight over them when necessary. In the trenches, however, which will now be brought more immediately under consideration, and which are designed not only to provide cover, but to be vigorously defended when attacked, the chief object of making a step in the rear would be, that the defenders, instead of waiting for the assailants in the bottom of the trench, might step out after giving their last fire, and thus interpose a fresh obstacle between them and their enemy, besides placing themselves in a better attitude for resistance.

te I. *c*. Fig. 1 represents the section of a small trench, and the parapet or breastwork that has been formed by throwing the earth up in front of it. The trench is 2½ feet deep, and the same width, having a rough step of one foot broad in the rear. The earth thrown out will make a parapet of a height nearly equal to the depth of the trench, without taking any precautions in building it up at a steeper slope than it will stand at of itself: we will assume that it is 2 feet high, which will make a total of 4½ feet from the bottom of the trench. A man, therefore, though he can reach to fire over the top of the parapet, has to stoop to be wholly concealed or covered by it, and it therefore affords as little protection as is worth the trouble of considering in this place.

The solid content of the excavation, from which the probable time it will take to

execute may be determined, is found by multiplying the depth and breadth of the trench together, for the superficial measure or area of the section, and that product by the length each man has to do. Here $2\frac{1}{2}$ feet multiplied by $2\frac{1}{2}$ feet is equal to $6\frac{1}{4}$ feet, and that product multiplied by 6 feet, which we have assumed to be the portion allotted to each workman, gives $37\frac{1}{2}$ cubic feet. The step is 1 foot broad and 1 foot deep, and being 6 feet as before in length, there will be 6 solid feet more to add, making altogether $43\frac{1}{2}$ cubic feet for the solid content of the mass of earth that has been removed.

Now if a man is only supposed to dig out 27 cubic feet in an hour, it will take him rather more than an hour and a half to remove $43\frac{1}{2}$ cubic feet on level ground.

Plate I.

d. Fig. 2 affords more cover, for the top of the parapet is 6 feet above the bottom of the trench. The best way of executing such a profile would be to sink a trench 3 feet deep and 3 feet wide, and to throw the earth about 2 feet in front of it; so that in the progress of the work, when the trench was found to be too deep to stand in and fire with convenience over the top of the parapet, a little step might be cut out of the solid left in front, for a banquette, as shown shaded in the section; and another step of the same description in the rear would complete it as far as it went. The steps might be 18 inches wide, and the same depth.

The area of this section is nearly 14 feet, the trench itself being 9 feet, and the two steps $4\frac{1}{2}$ superficial measure, which, multiplied by 6 feet, the length of the portion allotted to each workman as before, gives 84 cubic feet, or about 3 cubic yards, for the solid content of the excavation; and therefore, under the presumed data, it would be completed in three hours: still, however, it will be observed, that it offers no impediment in itself to an enemy, and men could only be drawn up in single file for its defence, from there not being room for more.

e. A trench of the dimensions shown in fig. 3 might be completed in five hours on the presumed data, and being roomy enough to dispose men in double files for its defence, and high enough to screen and cover them, may be considered as large as is necessary for merely fulfilling those conditions; for if more time could be devoted to strengthening a post, or if other circumstances were favourable, it would become a consideration whether some profile of a different form could not be substituted with advantage for such as only afford cover without opposing any obstacle to the advance of a hostile force.

f. Fig. 4 is a form of breastwork that might be adopted for obtaining cover in rocky or marshy situations, where a ditch or trench could not be made deeper than 1 or 2 feet; and if there were plenty of men, they might be set to work in two lines, and get it completed in half the time it would otherwise take, either by sinking on each side of the proposed situation, or by arranging the men in two lines behind it, as shown in the figure, where the situation for the second line of workmen is shown at *a*.

To work on both sides the breastwork, which is the quickest way, it would have to be considered what breadth of ground the breastwork with its slopes to the front and rear would stand upon, and what breadth the banquette and berm ought to be. These particulars being determined, two parallel lines would be roughly traced on the ground with pickets at the required distance. The workmen would be drawn up facing each other on these lines, and would work backwards, throwing the earth into the space between them, which some spare men would form into the breastwork.

Here sinking only 2 feet, the breastwork must be raised $4\frac{1}{2}$ feet to obtain cover. Suppose the slope on the inside is made steep by building it up with sods, or other materials, so that it only occupies 18 inches of level ground. The outside slope being left to find its own level, will require a base equal to its height, or 4 feet

6 inches; and if we add 2 feet for the thickness of the breastwork at the top, it will cover 8 feet of ground. Then if the banquette is made 2 feet broad, and the berm 1 foot, the distance between the two lines of workmen will be altogether 11 feet.

Under the second supposition, if the two lines of workmen were drawn up one behind the other, and both working to the same front, the distance between them might be from 4 to 7 feet, according to the depth.

The level of the ground in this instance forms the banquette or step to fire from. There will be about 5 cubic yards in 6 running feet of breastwork, and as there are supposed to be a double number of men at work, it ought to be finished in two or three hours.*

g. This mode of executing work may also be adopted with advantage in other cases when time is an object, and there are plenty of hands, or when it is of importance to strengthen and give height to breastworks in particular situations. But as far as this profile is concerned, it is to be observed, that it would afford cover to an enemy when he got at it, without opposing any impediment to his advance, which it is always very desirable to avoid.

h. Should the ground be rocky or very hard, as in a road or street, cover may perhaps be more expeditiously obtained by raising a breastwork from rubbish or materials brought to the spot in baskets, sand-bags, or barrows, than in attempting to sink at all. Different expedients are shown in Plate II. figs. 11 and 12.

i. Having thus far detailed the most expeditious modes of providing cover for men, it may now be worth while to consider whether in securing that advantage for the defenders, you cannot at the same time add another, in opposing an *obstacle* to an enemy, by excavating a ditch in *front* of the breastwork in place of making a trench in *rear* of it. A ditch to stop people at all, should be at least 8 or 9 feet broad, and 6 or 8 feet deep: in more Permanent Works it would of course be considerably more.

Plate I.

k. Fig. 5 shows the general dimensions which such a profile might have. The ditch, it will be observed, is of a triangular form, the area of which, for calculating the quantity of earth to be moved, will be found by multiplying its breadth by *one-half* its depth, that is, 9 feet by 4 feet, which gives 36 superficial feet; and that multiplied again by the length of the portion each man has to execute (we will here say 4 feet, as the breadth is considerable) will be $36 \times 4 = 144$ cubic feet, or about 5 cubic yards in each portion of 4 feet; which, considering the increased labour arising from a greater depth than has hitherto been contemplated, would not probably be completed in less than six hours by the same workmen. Some spare men, probably equal to one-half the number employed in the ditch, would also be required for ramming the earth, and forming the breastwork. Thus on 100 feet in length there would be twenty-five men working in the ditch, and twelve additional, making in all thirty-seven; whilst in the common trench-work, which has hitherto been under consideration, only about seventeen workmen have been shown to be necessary for every 100 feet.

l. A profile, such as that now under discussion, therefore requires not only longer time to execute, but double the number of men; and it would not seem advisable to undertake it, unless there were a reasonable probability of its being completed before an attack could be made; for if an enemy came upon it when in an unfinished state,

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* When from circumstances the depth of a trench or ditch is very limited, the probable time it will take to form a breastwork out of them, is more readily determined by estimating the content of the *mass* to be raised, than the *excavation*, as in the preceding cases, because the breadth of the latter will probably be irregular.

it would be almost useless, and the labour, which, if otherwise applied, would have secured at least good cover, would thus be thrown away. Still, however, the advantages it offers should not be lost sight of in situations where a determined stand is to be made, and on very accessible points, or to shut up roads or streets, etc., even if the rest of an intrenchment were differently arranged. As far as the means of resistance is concerned, it is obviously of more advantage to have a ditch in front of a breastwork than a trench in rear of one; and the only point to be determined is, whether there is *time* and *means* for executing it: and it is on this point that an Officer will have to exercise his discrimination, when he has carefully considered the various circumstances of his situation, which will have influence upon it; and which have already been detailed.

m. Such a profile may further be much strengthened by planting a row of palisades in the ditch, or even by driving stakes in and sharpening them, or making what may be called a perpendicular abattis, by planting brushwood upright in the bottom, with the ends sharpened, as shown in figs. 5 and 6.

Plate I.

An expeditious way also of adding to the difficulties of an assault, is shown in fig. 7, where common hurdles or gates, rails or brushwood, laid on the ground soon after commencing the work, and their extremities buried under the parapet, may be made use of; the earth underneath them, shaded dark in the figure, should be cut away when the ditch has been sunk to its full depth, fig. 7.

Plate II.

Short posts laid horizontally every 8 or 10 feet in the same situation, and long rails or a chain afterwards nailed to them, would be a ready expedient: the ends should project about 2 feet over the ditch, and stand at least 6 feet above the bottom of it.

n. It is to be observed that in all the foregoing cases, only a *minimum of cover and means of resistance* has been sought for in a *minimum of time.* It has been shown *what can be effected in a few hours;* it may so happen, however, that time is given to improve upon the profiles described, as would be the case if an advanced post were held for some days in succession, and each Officer in command had done what he could towards it. These improvements would consist in strengthening the breastworks, making the ditches deeper and wider, and planting more redoubtable obstructions; and such opportunities must never be thrown away, as the means of defence, and the security afforded, will be augmented in proportion.

o. It may be remarked, that such breastworks as offer little or no impediment of themselves to an enemy, if well laid out, permit the defenders to charge over them in line if they wish it, and still possess one of the principal attributes of any work, which is that of *screening them from previous observation.* But a forward movement from those that do offer an obstruction, must be through an opening, and therefore on a narrow front.

Now the space between a breastwork and an obstruction placed in front of it is ground belonging to the defenders, which, if circumstances permit, should be disputed; and as an enemy would probably be in some confusion in forcing his way through such obstruction, a favourable moment would doubtless occur for making a sudden charge, which, supported by a good flank fire, ought to be successful. These advantages should never be lost sight of in arranging the General Plan of Defensive Works, and determining the profiles they shall have. The salient angles of the intrenched lines are the points most open to attack, and it will be observed that the profile of the lines, terminating in those salients, has a ditch in front, which presents more or less of an obstacle; whilst the profile of the line adjoining the battery in the centre, is only that of a trench for providing cover, because it is not in a situation open to attack.

COMMUNICATIONS THROUGH BREASTWORKS, &c.

p. When an opening or passage is required through a breastwork or stockade, it must be arranged so as to be easily closed and defended. These objects may be in some measure secured by disposing the lines in such forms as are represented in figs. 8 and 9, and providing rough strong gates, CHEVAUX-DE-FRISE, or something of the sort, for quickly shutting them up. When houses are concerned, as in a street, the BARRICADE may extend quite across, and a communication be made round the end of it, by breaking through walls, as shown in fig. 10.

SECTION III.—DEFENCE OF HEDGES, ROADS, &c.

a. In the foregoing explanation of the Details of Breastworks, an attempt has been made to show the least possible time in which decent cover could be obtained when working on a level plain, unaided by any advantages of ground and situation; and it must be confessed it is rather a damper to one's ardour to find, that five or six hours of hard work may be calculated upon, before anything like comfort can be obtained under such circumstances; and that the people who should be kept fresh for resisting an attack, are likely to be worn out by their exertions in preparing for it.

This, however, happily, is by far the worst side of the picture; for with a moderate share of luck, some little slope or broken ground will offer itself; and some hedge or ditch, bank, wall, road, or wood, will be found, either placed exactly as if it were there on purpose to be defended, or a plan could readily be arranged for turning it to some account. An eye is put into a man's head to be made use of, and it only requires a little previous exercise of that organ, to see all these natural entrenchments and local advantages in almost every possible circumstance of ground and situation.

b. An endeavour will be made to explain by the Sketches in the annexed Plates, in reference to the Second Class of Works, the simple means which are most in use, and which appear adapted for improving, and deriving advantage from such local objects as are most commonly met with, in the hope of showing, that by the *judicious application of a very little labour*, a serious, and in some cases an almost insurmountable obstruction, may be formed. (See Plates III. IV. and V. figs. 14 to 30.)

Fig. 14 represents a hedge on the top of a steep bank, which has been cut down within 2 feet of the ground; the branches have been carried to the front as an obstacle, and two small steps have been made on the slope, the one to load on, the other to fire from.

Fig. 15 is supposed to be the same situation, but defended in an opposite direction. The hedge might be felled as an obstacle, leaving the stumps 2 feet high to screen the men; or it might be cut thin and left standing, if it were considered better. The slope in front is made steeper, and a little hollow is made to fire from, kneeling.

Fig. 16.—A ditch on the side of the enemy is supposed to have been deepened, and the earth and sods formed into a breastwork on the reverse of the hedge; where a small trench has also been made, to obtain additional cover.

Fig. 17.—The same, fronting the other way; the hedge felled as an obstruction, or cut thin, so as to give no cover to an enemy, and left standing. The ditch deepened to 6 feet, and a small breastwork made from the earth thrown out of it, and from a trench in the rear.

Fig. 18.—A double post and rail. Brushwood is interlaced in the front rail as an obstacle, and a breastwork is made leaning against the other to afford cover.

Fig. 19.—A bank, with double ditch. One ditch has been deepened, and the other partly filled up.

Fig. 20.—The edge of a quarry, or steep bank: a very defensible situation.

Fig. 21.—A wet ditch, or brook. The breastwork made from a trench in the rear.

Fig. 22.—A road. Both fences felled as obstructions, and a breastwork placed for defending them.

Fig. 23.—A hollow road, arranged in a similar manner.

Figs. 24 and 25 are profiles on a bare steep bank, to show the way of obtaining cover in such situations.

c. It may be remarked, that as obstructions placed under a close fire in front o Temporary Works are essential to their being properly defended, it will be a consideration whether a hedge would be more conveniently converted into such an obstruction, as in fig. 17, or be made to form part of a breastwork, as in fig. 15.

d. Before setting his men to work, it would be necessary that an Officer should have a notion of the time it would take to execute his projected defences: for this purpose he might pace the whole length of his proposed line, and then, by forming an idea how long it would take one man to finish a certain portion of it, say 4 or 5 yards in length, of deepening a ditch, scarping a bank, of felling a fence, he would see whether the number of men at his disposal could complete the whole in a given time, and would curtail or enlarge his plan accordingly, and distribute his men at intervals of 4 or 5, or 7 or 8 yards, as the case might be; for it is impossible to offer any defined Rules which shall apply where circumstances are ever varying.

A stick may be cut for measuring out the portions, and stakes may be driven in for explaining the slopes and the general form of the profile that is required.

SECTION IV.—DEFENCE OF WALLS.

a. Walls are readily made available for purposes of Defence by loopholing them; the mode of doing it varying with their height and situation.

b. It is a General Rule, that loopholes must be so placed, as that an enemy, if he succeeds in rushing up, shall not be able to reach so as to make use of them; for it is clear, that if he stands on the same level as the defenders, the loophole would be adapted for serving the convenience of *both* parties, which is not their object.

To obviate this inconvenience, loopholes should be placed 8 or 9 feet above the ground on the outside; but on the inside, the banquette or step, from which the defenders are to fire, should not be more than about 4 feet 6 inches below them, which may be assumed as a convenient height for the purpose, as already explained in treating of Breastworks. A portion of the wall also, not less than 18 inches high, should be left *above* the loopholes, where there is opportunity, for the purpose of screening the men's heads when giving their fire.

c. These points are attainable in several ways, and circumstances must decide which is the most convenient; for example, if a wall were 10 feet high, the loopholes might be pierced within 18 inches of the top, and a temporary stage might be made of casks, waggons, ladders, &c.; or an earthen banquette might be thrown up inside, for the people to fire from (Plate V. fig. 26). And in cases where a very determined resistance was to be made, a second row of loopholes might be arranged, as shown in that figure. On the other hand, if a wall were only 6 feet high, the loopholes might be pierced 4 feet 6 inches above the level on the inside, and a ditch cut on the outside to obtain the requisite height, which arrangement would save the trouble of making any banquette (fig. 27).

d. The quickest way of making a loophole is to break a wall down from the top to a depth of 2 feet, in the form of a narrow fissure, at intervals of 3 feet or more apart; and as this can be done with common pickaxes if there are no better tools at hand, it will generally be found a more convenient mode than cutting them through the wall, when time is an object. Such loopholes will appear as shown in fig. 28: it will

be seen that they are not quite so safe to fire from as others, but this inconvenience may be partially remedied by filling the upper part with a stone, a log of wood, a sand-bag, &c.

e. If a wall should be very low, or there were not time to make loopholes, a piece of timber, or the trunk of a tree, supported by a couple of stones, on the top of it, would be a ready expedient, and men could fire from the opening under it, as in Plates V. and VI. fig. 29. Or sand-bags, if they were at hand, might be laid there, having loopholes between them (see fig. 33). Or large stones or sods might be placed there in default of sand-bags. A man of resource would seldom find any difficulty in appropriating something to his purpose.

f. The temporary loopholes that are made in walls or buildings are not of course confined to any regular form; they are merely holes to fire through, made in the required direction, and so as to see the ground, from within a few yards of the wall or building in which they are pierced, to the extreme range of a firelock, affording also the opportunity of firing a little to the right and left.

To secure these points, the absolute dimensions will vary with the thickness and height of the wall: the width of the hole outside, however, need not exceed about 3 inches; but the width inside should, if possible, be equal to the thickness of the wall.

g. The best tools for breaking loopholes through brickwork or masonry are short iron bars, steeled at the head, called hand-borers. They are held in the proper situation by one man, and struck with a sledge-hammer by another. But if people are employed who have not been accustomed to the use of such tools, they would perhaps get on better each man with a crow-bar, which anybody can handle. A beginning might be made on the face of a wall with a pickaxe, which would very much facilitate proceedings. The time it will take to break through a wall will be best determined by a trial on the spot; for materials are so very various, it might lead to erroneous conclusions, were any attempt made to state a general average. Much also would depend on the tools and workmen, which adds to the difficulty of offering any precise data.

h. A wall exposed to the fire of artillery will not afford good cover, in consequence of the splinters that will fly from the materials whenever it is struck; but if time admits of it, this inconvenience may in some measure be obviated, by sinking a trench a few yards in the rear, and throwing the earth up against the *inside* of the wall; or a ditch may be sunk on the outside, and the earth be thrown over. The trench is best, as it will give additional protection to the men; but the ditch may be required as an obstacle, or to give height to the loopholes, and therefore, as usual, circumstances must decide what is best to be done. It is not contemplated that there would be opportunity for giving this embankment sufficient thickness to make it shot-proof, but most of the splinters would bury themselves, if it were only 3 or 4 feet thick.

SECTION V.—STOCKADE-WORK.

STOCKADE-WORK may be substituted with advantage for Breastworks, when there is timber to be had in abundance, especially if it can be covered from the fire of artillery. It has this advantage over earthen-works of very small profile, that if made high enough, it is not easily got over, and therefore in itself it opposes an obstacle to an enemy, which they generally do not. (See Plate V. figs. 32 to 34.)

Stockade-work may be made with the rough trunks of young trees, cut into lengths of 12 or 14 feet, and averaging not less than from 10 to 15 inches in diameter. They should be firmly planted upright, in a narrow ditch, 3 or 4 feet deep, either

close together, or with intervals of a few inches for firing through. The interstices in either case should be filled up, to a certain distance, with shorter pieces of timber to protect the men; and the loopholes should be arranged with the precautions adverted to before.

A banquette or step will generally be required on the inside; and a ditch, and any other obstacle on the outside, that can be made in the time, will add to the difficulties of an assault. In defending a stockade, the means of stopping up any partial breaches which may be made by artillery should be at hand, and a flank fire across the front is very essential, as it will be obvious that were an enemy to succeed in rushing up to it, he would be under cover from the direct fire of the loopholes.

MEMORANDA RELATING TO VARIOUS DETAILS OF FIELD-WORKS AS THROWN UP IN FRONT OF LISBON.*

(Plates XI., XII., XIII., XIV.)

"Les principes des fortifications de campagne ont besoin d'être perfectionnés: cette partie de l'art de la guerre est susceptible de faire de grands progrès.

"Les fortifications de campagne sont toujours utiles—jamais nuisibles, lorsqu'elles sont bien entendues."—*Conversations de Napoléon, par Montholon.*

Workmen.—The manual labour of the lines was performed by the peasantry of the country and two regiments of militia. The former were obtained by conscription, and were relieved weekly; the latter worked as a permanent duty. The peasantry were paid six vintems per diem as labourers, and twelve vintems per diem as mechanics; and the militia at one-third those rates.† Subsequently, as the work increased and lengthened almost into a permanent occupation for the peasantry, their rate of wages was augmented to ten vintems per diem for labourers, and sixteen for artificers; the militia continuing to be paid at the original rate. In August, 1810, when more than 2500 men were working in a body at Alhandra, and the ordinary supply of the town would not furnish sufficient provisions for such augmented numbers, the Officers of Engineers took upon themselves to make requisitions on the neighbouring districts for bread sufficient to supply each workman with a pound per day, and saw that the value was regularly stopped from the men's wages at the end of the week. In the winter of 1810 and 1811, when the country was totally exhausted of provisions, this system was improved into a regular supply of a pound of biscuit per man, issued by the British Commissariat, for which three vintems per day were deducted from the wages of the peasantry.

Superintendence.—The number of Officers of Engineers employed on the lines never exceeded seventeen at the same time, viz., eleven British, two Hanoverian, and four Portuguese; and the number of their own soldiers never exceeded eighteen rank and file; but they had the assistance of more than one hundred and fifty soldiers of the line, principally artificers, selected from the regiments at Lisbon. The latter were under the charge of a Captain stationed at Mafra, and a Subaltern at Alhandra, but were divided into two parties of two and three each throughout the whole extent of the country to be retrenched. In some of the districts a Subaltern Officer of Engineers, with that small number of English soldiers, utterly ignorant of the language, directed and controlled the labours of a thousand or fifteen hundred peasantry, compelled to work, many at the distance of forty miles from their homes, whilst their own lands lay neglected, and no Portuguese ever attended of higher authority than a *cabo*,

* By the late Major-General Sir John Jones, Bart., K.C.B., R.E.

† A vintem is 5·4 farthings.

equal, according to military classification, to a serjeant; nevertheless, during a twelvemonth of this forced labour, not a single instance of insubordination or riot occurred; and the great quantity of work performed should, in justice to the Portuguese, be more ascribed to regular habits of persevering labour in those employed, than to the efficiency of the control exercised over them.

Mode of Payment.—On commencing the lines, the Officers of Engineers were made public accountants, contrary to the regulations of the Service, which strictly prohibit it; and they had, in consequence, to take charge of large sums of money (all in silver) and make the weekly payments of the labourers' wages.

Every moment of the Engineers' time being devoted to the works, and no Officer having a secure place to lodge the cash, nor any competent person to keep his accounts, many were considerable losers by this duty, and the active service of the senior Officer of each district was altogether lost, one day in the week, whilst settling with the workman, each of whom individually received and signed in triplicate for his 4*s.* 1½*d.*, which useless formality rendered the payment of fifteen hundred or two thousand men the labour of many hours.

After some months, the impolicy as well as injustice of making the Engineers paymasters becoming apparent, an Officer of the Commissariat, with efficient clerks, was named for that duty, and made a regular round of the districts, paying the workmen on lists prepared and certified by the Engineers. In a similar manner, during the latter periods of the war, in carrying on works in detached situations, the Officer of Engineers was relieved from the responsibility of being a public accountant, by the duty of paymaster being allotted to an Ordnance Clerk or conductor of stores, who received a sum of money to cover the intended service from the Commissary-General, and disbursed it on the order of the Engineer in charge of the work.

Materials, Stores, &c., how obtained.—All materials, stores, implements, &c., were purchased by the Commissary-General on requisition from the Commanding Engineer, and the Officers in charge of the several districts only gave receipts for the quantities delivered to them, being in no way responsible for or consulted respecting the price.

Lieut.-Colonel Fletcher had a general authority from the Commander of the Forces to make these demands on the Commissary-General, and when he gave over the charge of completing the lines to Captain John T. Jones, and made him responsible for the future expenditure, he also transferred his authority to order materials, &c., which authority, so delegated, was found efficient. In like manner, Captain Goldfinch was subsequently invested with similar delegated powers and responsibility, whilst retrenching the position of Almada; and, generally speaking, each Officer, when employed in charge of a distinct work, had authority to make demands on the nearest commissariat station.

The gunpowder used for blasting during the formation of the scarps of the lines, the quantity of which was very considerable, also that used for mining the bridges and roads, was obtained from the Ordnance Commissary at Lisbon as wanted, on requisition addressed to the Commanding Officer of Artillery.

When mining was ordered in situations distant from any artillery dépôt, it was at first customary to draw cartridges from the nearest brigade of guns; but as this was invariably found to be a source of vexation to the Artillery Officers, a supply of gunpowder was latterly transported with the Engineers' stores, with cases ready prepared for given charges.

Trace of the several Works.—The redoubts were made of every capacity, from that
s XI. of fig. 74, limited by want of space on the ground it occupied to fifty men and two pieces of artillery, to that of fig. 89, for five hundred men and six pieces of artillery,

Plates XII. and XIII.

the importance of the object to be attained being the only guide in forming the dimensions. Many of the redoubts first thrown up, even some of the smallest, were shaped like stars (figs. 82 and 86), under the idea of procuring a flank defence for the ditches; but this construction was latterly rejected, it being found to cut up the interior space, and to be almost fallacious with respect to flank defence, the breadth of the exterior slopes being in some cases equal to the whole length of the flanks so obtained, as in fig. 86. Even when, from the greater size of the work, some flanking fire was thus gained, the angle formed by the faces was generally so obtuse, that it demanded more coolness in the defenders than ought reasonably to be expected, to aim along the ditch of the opposite face; and further, this construction prevented the fire of the work being more powerful in front than in rear.

In order to decide on the proper trace of work, it is necessary to consider whether its object be to prevent an enemy establishing himself on the ground on which it is to be placed, or whether it be to ensure a heavy fire of artillery on some other point in its vicinity. In the first case, every consideration should be sacrificed to that of adding to its powers of self-defence by flanks or other expedients. In the second, its powers of resistance are secondary to the establishment of a powerful offensive fire, and its trace cannot be too simple. Latterly, the shape of the redoubts was invariably that most fitted to the ground, (figs, 74, 75, 77, 83, 84, 85,) or such as the best parried the enfilade fire or musketry plunge of neighbouring heights, care being taken to present the front of fire deemed necessary towards the pass, or other objects to be guarded; and such will generally be found the best rule of proceeding.

Plates
and X

This recommendation, however, is not intended to apply to isolated works of large dimensions, and more particularly to those considered the key of any position. No labour or expense should be spared to render such works capable of resisting the most furious assault, either by breaking the parapet into flanks, or forming a flank defence in the ditch; for the experience gained in the Peninsula shows that an unflanked work of even more than an ordinary field-profile, if skilfully and determinedly assaulted, will generally be carried; for instance, Redoubt Renaud, Forts Picurina and Napoleon, &c. Nor does the serious evil of curtailing the interior space, which renders any breaks in the outline to procure flanks so objectionable in small works, apply to works of large dimensions; for it must be recollected, that in similar figures, whilst the length of the outline increases only in the simple ratio of the double, triple, or quadruple, the interior space or surface increases as the square of their like sides. Under this view the great work on Monte Agraça (fig. 72) must be considered as very defective, the flank defence being confined to an occasional break of a few feet in the trace, caused by a change of direction in the contour of the height, whilst the interior space is more than doubly sufficient for the number of its allotted garrison to encamp.

Interior and other Defences.—This work, however, had some of its most exposed salient points, or those most easy of access, or most likely to be assaulted, cut off by earthen lines of parapet, steeply revetted externally, and so traced as to serve for traverses to the interior. It had also three or four small enclosed posts formed within it; and the work at Torres Vedras (fig. 73) had each of its salient points formed into an independent post. These interior defences and retrenchments were intended to guard against a general panic amongst the garrison, which would necessarily be composed in part of indifferent troops, and also to prevent the loss of the work by the entry of the assailants at any weak or ill-defended point. Such interior lines to rally on are absolutely essential to the security of a large field-work. They serve as substitutes for the BLOCKHOUSE or tower, placed in the interior of all well constructed permanent earthen-works, and merit far more attention than they generally receive.

The small circular windmills of stone, which were frequently found occupying salient knolls selected for the site of advanced flèches, were readily converted into admirable interior posts of that nature; and many mills situated on the elevated points of the main defences were made to add greatly to their security by a similar conversion. (Figs. 87, 88, 89.)

Redoubt No. 109, occupying a very important and very exposed point in advance of the position of Oeyras, was deemed of so much value, that being commanded by a height between 600 and 700 yards in its front, in order to ensure some power of resistance after its parapet and scarps should have been destroyed, its artillery dismounted, and its interior ploughed up by a cannonade from the height, a gallery, loopholed for reverse flanking fire along the ditch, was formed behind the counterscarp, at the salient angle of the front faces, and a communication made to it from the interior, under the bottom of the ditch. The soil being of a hard chalky substance, which stood without support, fixed the adoption of this means of defence in preference to the ordinary caponière, which requires so much labour. (Figs. 83 and 97.)

XIII.
XIV.

The parapet of 109 was also cut *en crémaillère* to throw a musketry fire on the salient angle next the heights, and to screen the defenders of its left face from the enfilade fire of the heights. This mode of indenting the parapet, however, was not thought a good measure generally, it being found to add very much to the labour, and to abstract from the direct fire of the work an equal quantity to that it threw in a different direction; besides making the defence of the parapet rather complex for militia. Therefore, latterly, in those redoubts where any particular trace was not imperious, it was always preferred to make an additional face to the work, than to leave a salient angle so acute as to necessitate such extra support; and at Almada, this principle was carried so far as to render the contour of some of the redoubts almost circular. (Figs. 79 and 84.)

Situations of the Works.—Many of the redoubts were placed on very elevated situations on the summit of steep hills, which gave them a most imposing appearance; but it was in reality a defect highly prejudicial to their efficiency and defence, for the fire of their artillery on the object to be guarded became so plunging, as to lose half its powers; the musketry could not be made to scour the face of the hill sufficiently; and during the night both arms became of most uncertain effect.

The domineering situation of the redoubts, however, gave confidence to the young troops which composed their garrisons, protected them from a cannonade, and screened their interior from musketry, unless fired at a high angle, and consequently at random. These considerations perhaps justified the unusual elevated sites selected for most of the redoubts on the lines, though they cannot induce an approval of them as a general measure. Indeed, the ill consequences arising from height of situation was so strongly felt on the lines, that on very elevated points, particularly at Monte Agraça, in order to command the face of the mountain, flèches, or small redoubts, were established in front of the main work (fig. 72), on the projecting knolls which afforded the best flanking points. These advanced batteries were made of the same strong profile in front as the redoubts, and their gorges were equally secured, except that the rear parapets were formed as mere screens, so as not to give cover against the fire of the main work; and for the same object, the counterscarps of the rear ditches were sloped into the plane of the parapets of the commanding work. Even these flèches, though nearly doubling the garrison, saw the face of the hill less perfectly than the main work alone would have done, if placed on a height of a moderate and more regular ascent, which shows that very elevated situations for works are seldom to be preferred.

At some points, where it was deemed likely that the troops would act in combina-

tion with redoubts occupying the summits of very elevated knolls, flèches or field batteries were prepared for the field brigades in the best flanking or enfilading situations, much lower down on the face of the hill. This seems the most judicious mode of occupying a height as a field position, when the artillery can be placed under the effectual musketry fire of the redoubt; but on these lines, it being impossible to foresee which part might or might not be occupied strongly by troops, it was made a rule to put no artillery in battery, except within works capable of defending themselves. At some points, where space could not be obtained within the redoubts, the guns were placed on a lower advanced level, connected on its flanks with the defences of the redoubt (fig. 80). Some of the flank defences were limited to one or two guns; which could only be justified by the difficulty an enemy would find in passing the object they fired upon. It ought to be received as a general rule, that no flank can be formidable to infantry which does not contain at least three pieces of ordnance; and even to render a flank of three pieces very destructive, it must be in a situation of tedious approach, or in a work which cannot be run into.

Profiles.—The profile of the several works varied on every face and flank, according to its liability to be attacked or cannonaded, the only general rule enforced being, that all ditches should be at least 15 feet wide at top and 10 feet in depth, and the crest of the parapet have at least 5 feet command over the crest of the counterscarp.

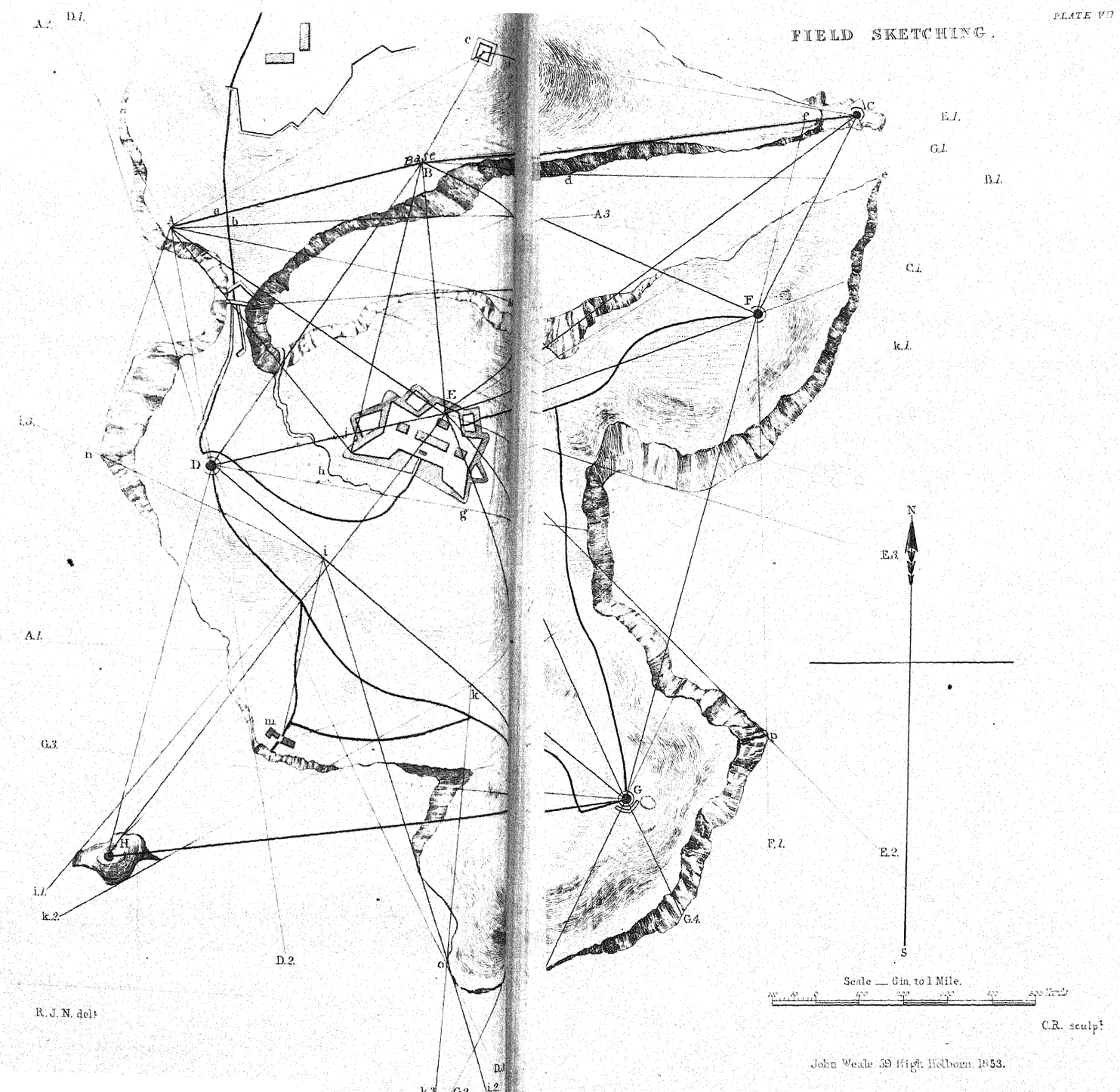
No parapet exceeded 10 feet in thickness, unless exposed to be severely cannonaded, and few more than 6 or 8 feet; and some, on high knolls, where artillery could not by any possibility be brought against them, were made of stone or rubble, less than 2 feet in thickness, to gain more interior space, and allow full liberty for the use of the defenders' bayonets. Many of the rear enclosures, when supported on precipices, were merely screens; and in some few cases, on the position near Ribaldiera, they were left to the precipice itself (fig. 76). The rear of advanced flèches, and other small works, situated within good musketry fire of the main defences, were generally closed with a very open but strong stockade (figs. 87 to 89).

In elevated situations, many of the banquettes were raised within 4 feet of the crest of the parapet, it being the rule to fix the level along each face at such height as would admit of the musketry plunging down the face of the hill, or at least seeing some yards of the glacis.

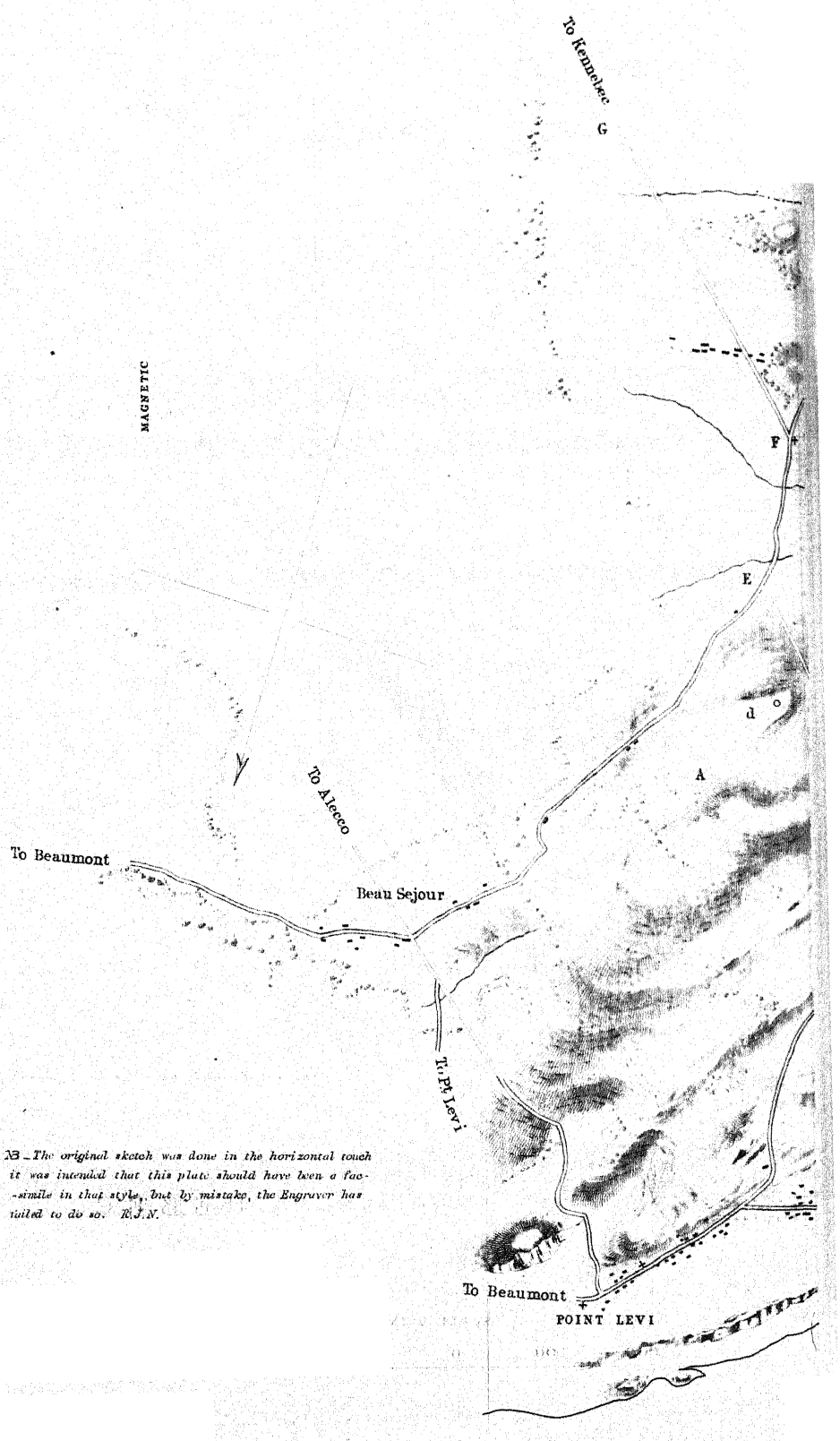
The exterior slopes were made greater or less, according to the tenacity of the soil; but it was found, after the first winter, that no slope cut through the natural ground had sustained itself at a greater angle than 45°, and in made ground the exterior slopes were washed away at that angle. Indeed, in consequence of the heavy rains in southern climates, it is almost essential to form some kind of revetment to works to keep them defensible during winter; and in 1811, most of the exterior slopes of the works of the lines were retained with dry stone walls. To ensure an efficient system of drainage should always be a principal consideration with an Officer on commencing a work. Some redoubts, deeply excavated, with the view to screen the defenders, particularly Nos. 101 and 102 at Oeyras, from neglect of this precaution, literally filled with water, in September, 1810; and the labour of forming drains, to keep their interior dry, was little less than that of constructing the redoubt.

The interior of the parapets was retained with fascines or sand-bags: the former stood perfectly well, except that those originally made, being composed of the smaller branches and twigs, became, during the summer, so readily combustible as to be considered unsafe; and latterly, only the larger branches, completely divested of their leaves and twigs, were worked into fascines, intended for interior revetments. The sand-bags rotted, and burst after the first winter.

FIELD SKETCHING.

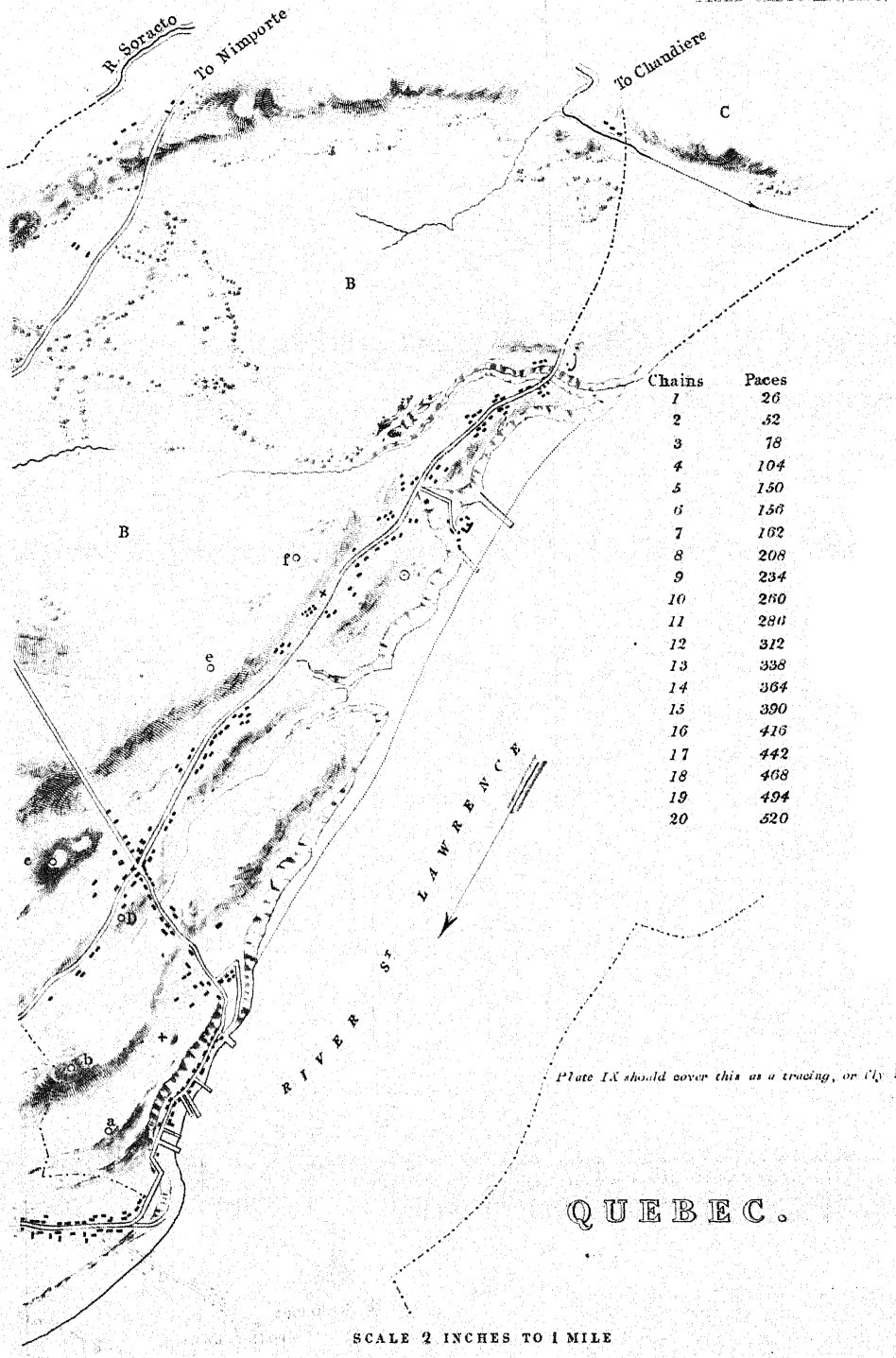


John Weale 59 High Holborn. 1853.



NB – The original sketch was done in the horizontal touch it was intended that this plate should have been a fac-simile in that style, but by mistake, the Engraver has failed to do so. R.J.N.

John Weale, 59, High Holborn, 1846.



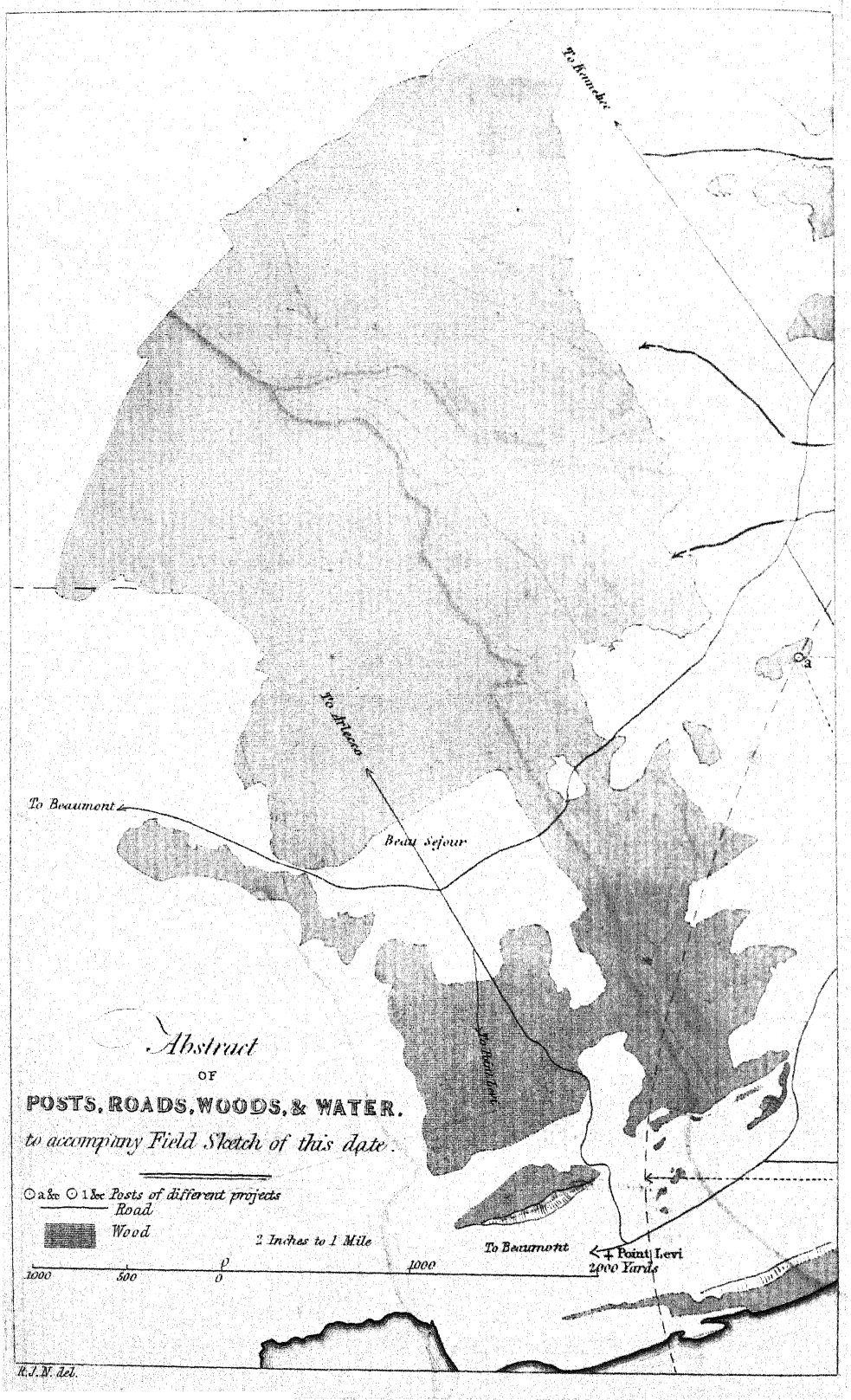
Chains	Paces
1	26
2	52
3	78
4	104
5	130
6	156
7	182
8	208
9	234
10	260
11	286
12	312
13	338
14	364
15	390
16	416
17	442
18	468
19	494
20	520

Plate IX should cover this as a tracing, or fly sheet

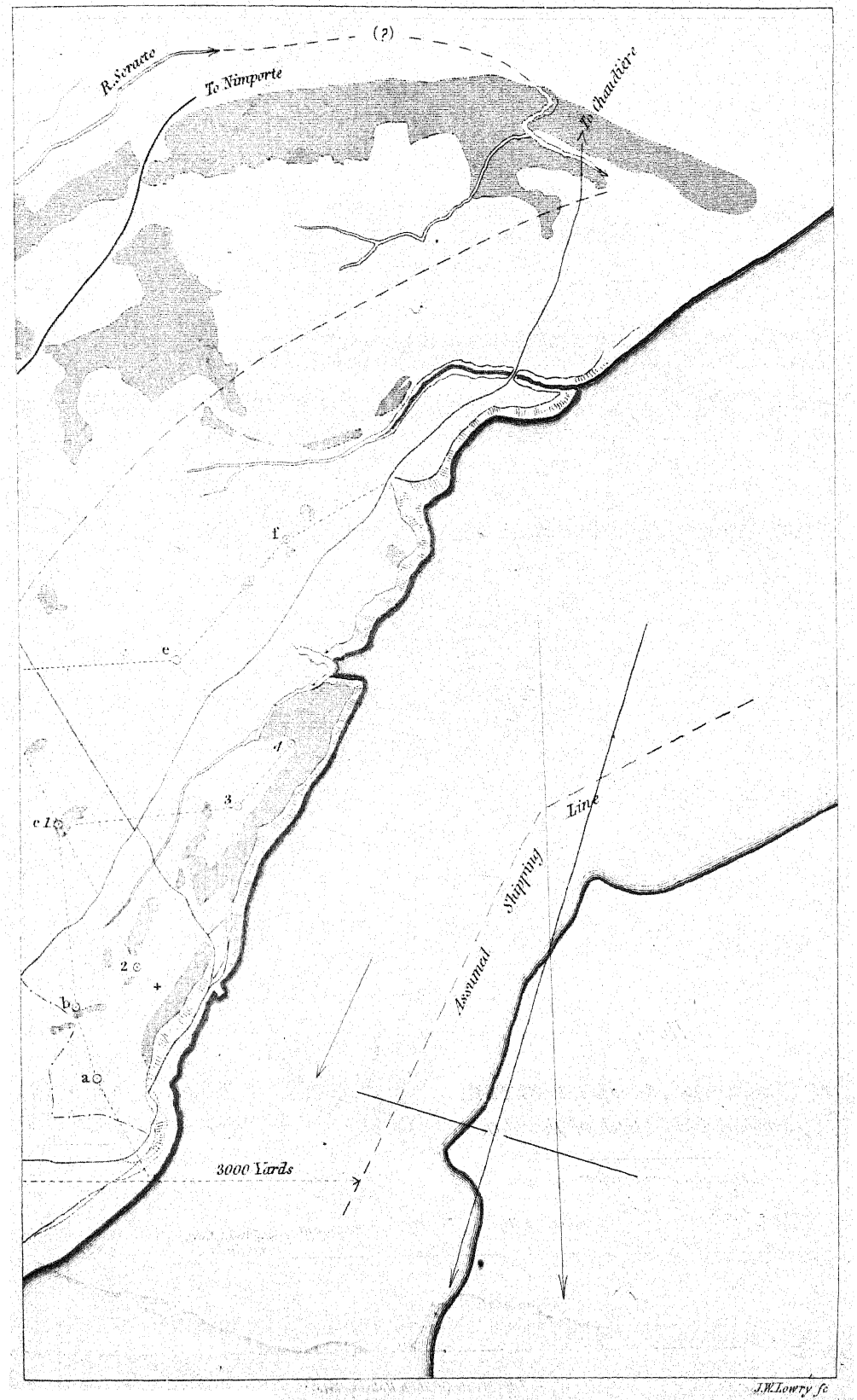
QUEBEC.

SCALE 2 INCHES TO 1 MILE

1000 500 0 1000 2000 YARDS.

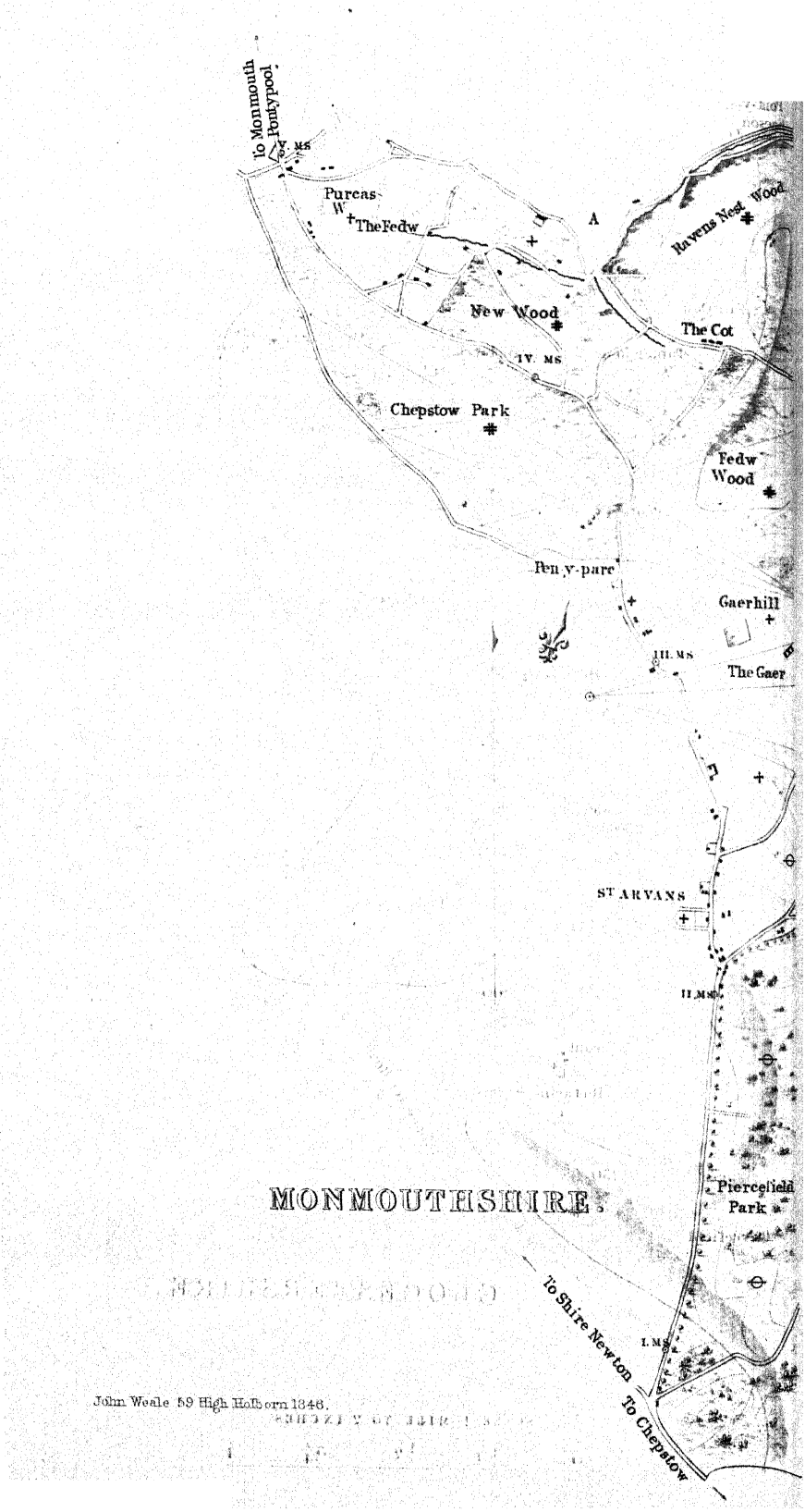


John Weale 59 High Holborn. 1846.

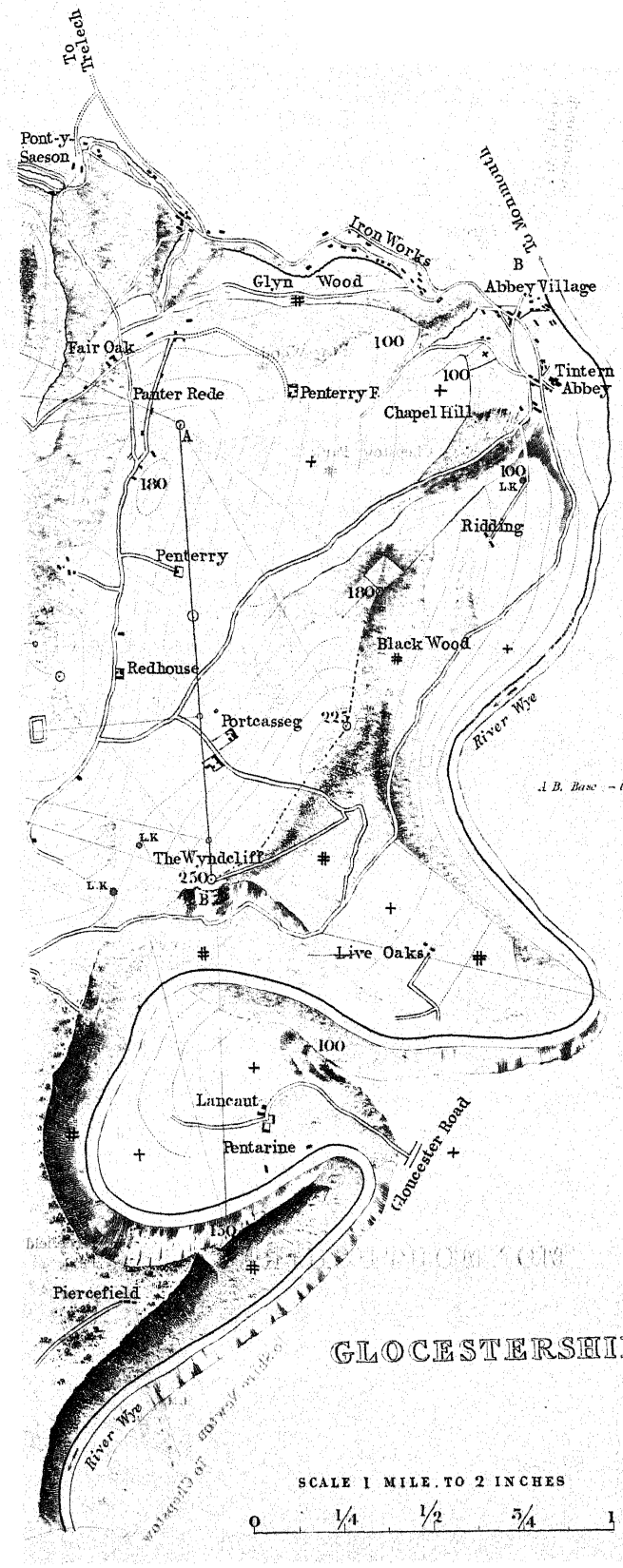


J.W.Lowry fc

John Weale 59 High Holborn 1846.



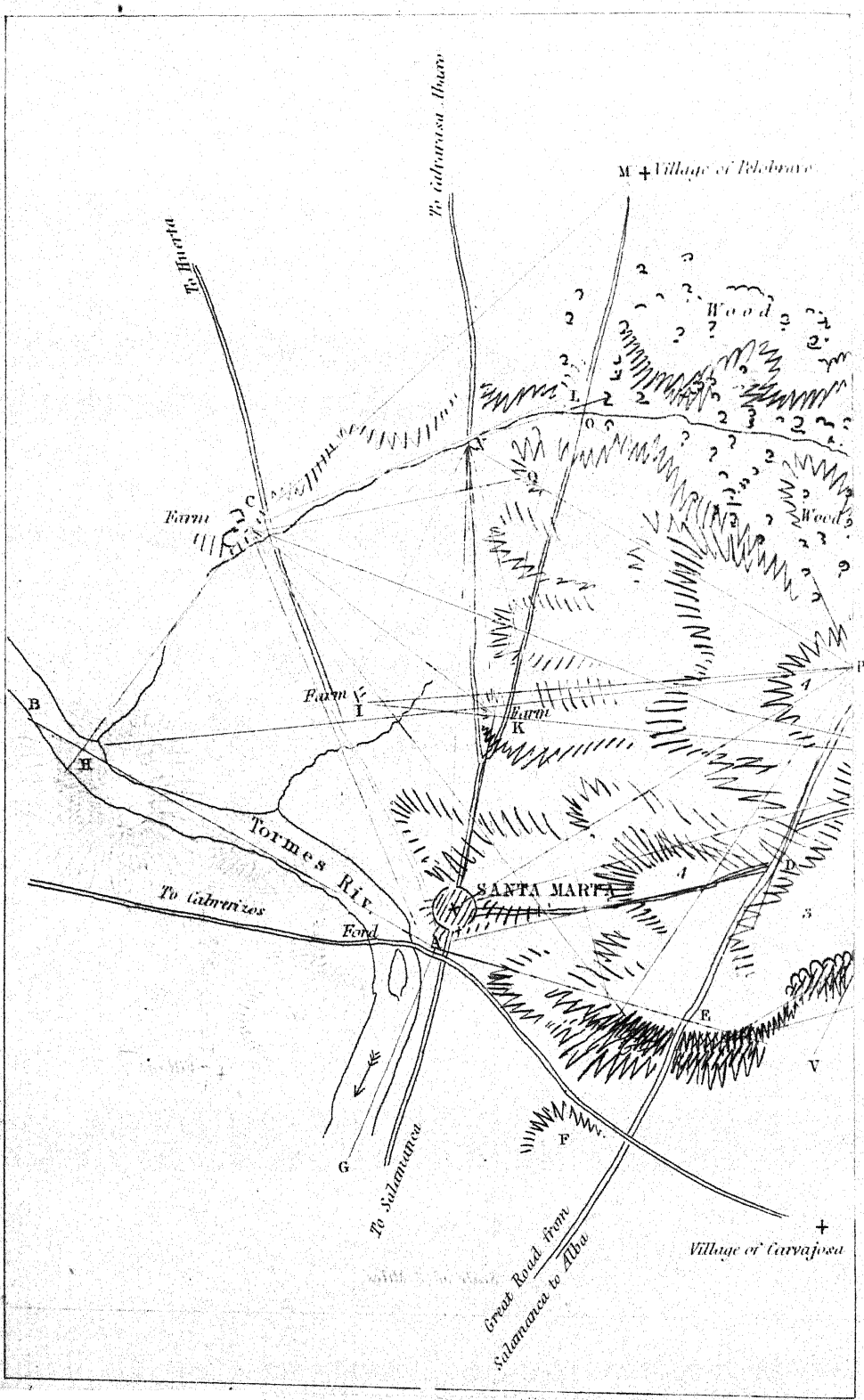
John Weale 59 High Holborn 1846.



GLOCESTERSHIRE.

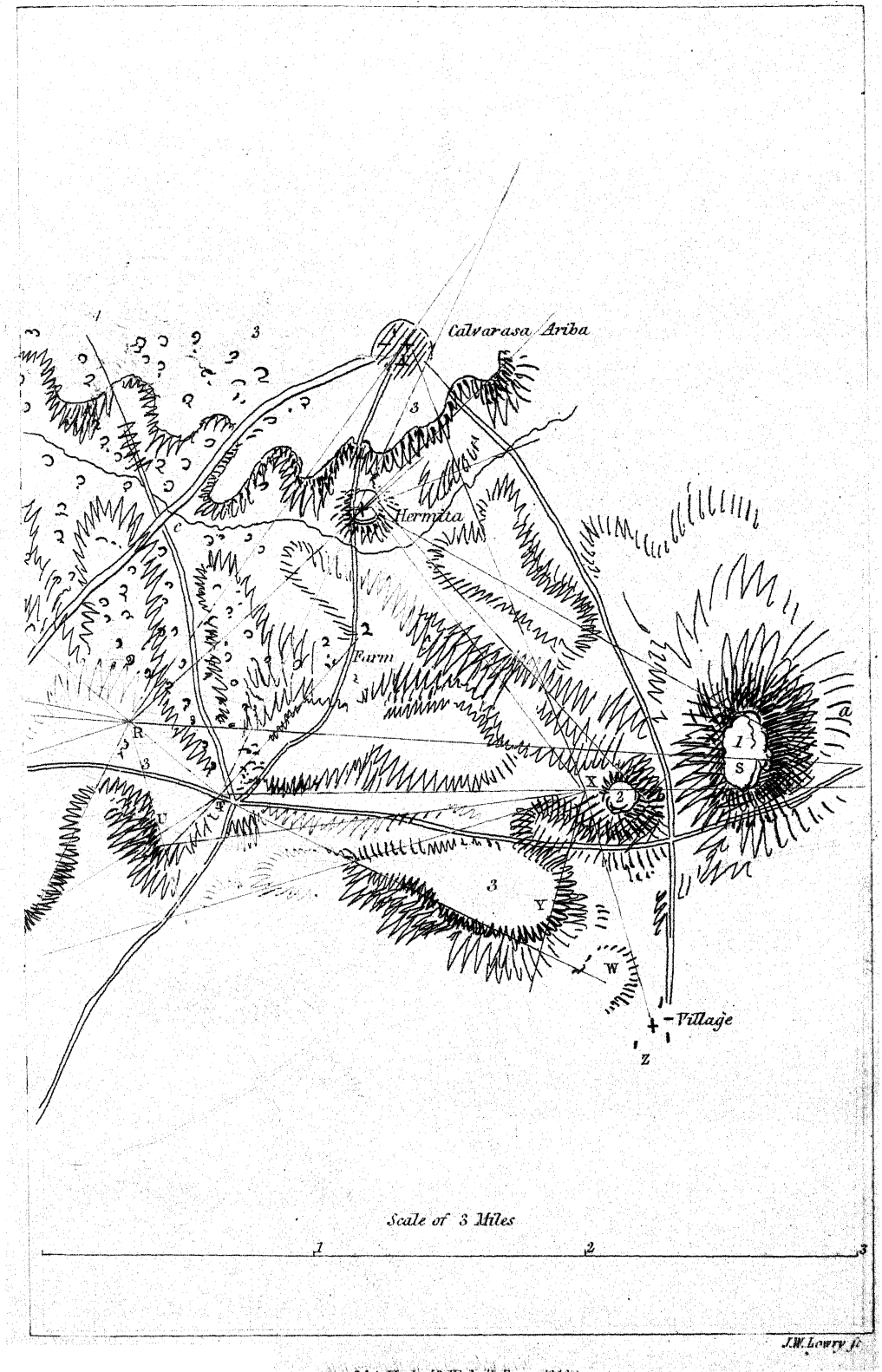
SCALE 1 MILE TO 2 INCHES

0 1/4 1/2 3/4 1



J.W. Lowry fc.

John Weale 59 High Holborn 1846.



J.W. Lowry fc.

John Weale 59 High Holborn 1846.



A drawing is given of the profile of several of the works in different situations (figs. 91 to 97): that of the redoubts on the heights of Almada (fig. 95) deserves particular attention, as those works stand in situations open to be violently cannonaded; and the hills forming the position are such as are most frequently occupied with works; and the profile was fixed after the experience gained in making the lines: it was as follows:

Height of interior crest of parapet	7 ft.	0 in.
Height of parapet above banquette	4	3
Thickness of parapet	14	0
Berm	2	0
Breadth of ditch at top	16	0
Depth below surface of ground	12	0
Crest of glacis below crest of parapet	5	6

In the profile of lines of flanked works, in low situations, where the interior space was not limited, the crest of the parapet was generally fixed at 10 feet above the level of the ground, for the purpose of a better command in front, and better covering the troops; and this height was thought to be the best adapted for attaining a good defence with moderate labour. Even with this elevation, no covered-way was formed to any line, but the crest of the glacis was kept 6 or 6½ feet below that of the parapet.

The redoubts of the lines being mostly thrown up as secure emplacements for guns, and to procure an open field for the fire of their artillery being the principal object attended to in their construction, they were mostly placed on the summit of the heights they occupied, so that each face might have a full command of the ground in its front, or of the point it was intended to protect; but, in other situations where the object of a redoubt was merely to prevent an enemy occupying a particular spot, it was, wherever practicable, constructed on an inclined plane on the reverse of the height, so that only its most salient point, or, perhaps, its front faces, rose over the crest of the hill (fig. 98). This defilement gives the work considerable protection from cannonade, and causes the front parapet to cover the rear lines and the defenders far better than if constructed on a horizontal plane, and should generally be adopted in situations where an enemy cannot establish batteries in its rear, and invariably in the construction of lunettes or flèches in advance of a fortress; as beyond the advantages above mentioned, it causes the interior of the work to be completely seen from the place.

In this construction the rear enclosure, whether palisades or a wall, should be made of a strength to resist light howitzer shells pitched over the parapet, but not so strong as to afford cover against the heavy guns of the place.

Stores and Provisions.—In each redoubt wholesome casks were provided, and placed in security, to contain four quarts of fresh water per man for the calculated garrison, besides the tubs with water for the use of the Artillery: and a dépôt of intrenching tools was also provided, in the following proportions:

	Shovels.	Pickaxes.	Felling-axes.
Works for 400 men	10	6	3
„ 300 „	8	4	2
„ 200 „	7	4	2
Smaller	6	3	2

Monte Agraça, proportion for 1500 men.

MAGAZINES.—The magazines were formed of splinter-proof timbers, about 10 inches by 8, placed at an angle between 45° and 50° against a substantial traverse; and

wherever an efficient drain could be made around them, their floors were sunk one, two, three, and even four feet below the level of the interior of the work; which excavation, and the relative height of the redoubt with respect to the ground in its vicinity, served to regulate the length of the timber, so as to have the top of the magazine sheltered from direct fire.

The magazines were lined internally with plank, and strengthened externally with 2 feet of earth in sand-bags, over which tarpaulins were spread; and, thus protected, these magazines were found sufficiently dry.

PLATFORMS.—The platforms, as originally laid down, consisted merely of a plank for each truck, but during the summer and autumn of 1810 they were all replaced by platforms of ordinary construction. Many of the redoubts being on undulating heights, and the guns being mounted on extremely low carriages, it required undeviating attention to keep the front of the platform on a sufficiently high level to ensure the guns clearing the intermediate swell of the height, so as to strike an object at the foot of the slope. In such situations, the eye will frequently attain an object which the gun on its lower level will not.

PALISADES.—The palisades in the ditches were mostly young fir-trees from 4 to 5 inches in diameter, roughly pointed, and fixed 3 or 4 feet into the ground, with a riband very low down, and, when the ditches were broad, much nearer the counterscarp than the scarp.

In the last campaign, the palisades of the redoubts thrown up near the Montagne de la Couronne, in the Pyrenees, where wood was plentiful and cost nothing, were made of trunks of trees placed close together at the foot of the escarp, and were found almost equal to a masonry revetment.

The best disposition of the ordinary palisades, in works with wide ditches, was thought that adoped for the advanced redoubt, No. 109, at the position of Oeyras (fig. 97), where they were fixed as fraises along the counterscarp, about 2 feet below its crest, with an inclination towards the bottom of the ditch. Fraises in that situation are little likely to be injured by a front fire of cannon or howitzers, and the manual operation of cutting them away is extremely difficult, besides the men, whilst so employed, being exposed to the fire from the parapet of the work. This mode of fixing fraises was also partially applied to some salient angles, on the approach to which little fire could be brought.

It should be observed, however, that fraises, being much more liable to be broken down by vertical fire than palisades, are more adapted for field than revetted redoubts, as vertical fire can seldom be brought against the former, and it ought to form the basis of attack of the latter.

BARRIERS.—Each redoubt was closed with a barrier-gate, and a bridge of joists and planks.

For these four last-mentioned services more than 50,000 trees were received between the 7th July and 7th October, 1810: the greater part being firs from the Royal forests, no payment was made for them.

ABATTIS.—The abattis was formed solely of the stems and boughs of whole trees, well pointed, all the smaller branches being cut off, so that the front of the abattis afforded neither cover nor concealment to an assailant, although it presented a barrier of spears, five, six, and seven feet in height. The abattis were usually placed from 20 to 30 yards in front of the work, each stem and large branch being firmly staked down into the ground; and, when practicable, the trace was so disposed as to be flanked along its front by some of the defences.

Obstacles in this situation are undoubtedly the best means that can be devised for aiding the defence of works, and are seldom sufficiently attended to.

The great object of defence should be to contrive some expedient to check the assailants, and cause them to halt, if only for two or three minutes, under a close fire of musketry from the parapet. Such an advanced obstacle has ten times the effect of one of equal difficulty opposed to an assailant when he has closed with the defenders of a work. He knows that in the latter case he has but to overcome one difficulty to obtain complete success, whereas in the former case the troops exhaust their ardour, and lose their formation, on a mere preliminary effort; and every one must have felt how extremely difficult it is to revive confident boldness, and restore order for a second effort after a check.

Fir-trees were found the least, and olive-trees the best, adapted to form abattis.

TROUS-DE-LOUP.—The trous-de-loup were at first made of the ordinary dimensions and numbers; but subsequently an increased number of rows (eight or ten) of pits, only 2 feet or 2 feet 6 inches in depth, well staked at bottom and in the intervening spaces, were considered preferable, as affording no cover within them for men to fire on the work before which they might be placed, and presenting great impediments to the advance of an assailant.

During the occupation of the lines, trous-de-loup were formed in front of part of the position of Via Longa, consisting of a triple row of inverted cones, 9 or 10 feet in diameter at top, and of the same depth. These were found to be a most formidable obstacle, but were perhaps larger than absolutely required, as it is only necessary that trous-de-loup should be of a depth to prevent an assailant getting into them and firing over their tops, which 7 or 8 feet will effect.

Whenever practicable, from the height of the profile or the fall of the ground, the rows of trous-de-loup were concealed and protected from cannonade by forming an advanced glacis with the earth excavated from the pits.

ARTILLERY.—The provision of artillery, ammunition, and artillery stores, was arranged by the Portuguese in the arsenal at Lisbon, on memoranda sent from time to time by the Commanding Engineer, and the guns were mounted by parties of Portuguese gunners detached from thence, as the works were prepared to receive them. It was gratifying to observe, on these occasions, by what persevering and patient labour the peasantry, with their rude means of transport (merely the common cars of the country, pushed forward by oxen), succeeded in transporting 12-pounders into situations where wheels had never before rolled, and along the steep sides of mountains where horses would have been useless.

Although the armament of the lines ultimately amounted to nearly double the number of pieces of ordnance originally contemplated, the zeal and perseverance of the Portuguese General Rosa smoothed all difficulties, and his activity and resource seemed to render the supply of guns, ammunition, and the means of transport, inexhaustible; and, highly to his credit, everything supplied, through rude and inconvenient, proved efficient and substantially good. The Portuguese officers and gunners employed on this duty were also zealous and active, and took extremely good care of their stores and ammunition. Their numbers, assembled on the lines, amounted to 3208, regulars and irregulars.

Calculation of Garrisons.—As a general rule, the garrisons of the redoubts, and the number of troops required to man the retrenchments, were at the commencement calculated on an allotment of two men per yard running of parapet for all lines; but after some time, this calculation was deemed too considerable, and the numbers were fixed at two men per yard running for all front lines, and one man per yard for all rear lines, deducting for the spaces occupied by the artillery; an addition to or deduction from these numbers being made by the Commanding Engineer in all cases where deemed expedient from local causes.

Admitting each man to require three feet to enable him to use his musket freely, this latter calculation will (whatever be the figure of the work) ensure the parapet being sufficiently manned, and leave a reserve to supply the place of those killed, or, in large works, to charge the first of the assailants who may penetrate into the interior. It was therefore deemed preferable to the more scientific formula for allotting a man to a certain number of square feet of the interior space, which rule, though well calculated to apportion the garrison of every sized work in a similar ratio between its interior space and its length of parapet, seems too much the result of theory, which requires that each man of a garrison should have a certain space for his accommodation; whereas in practice such does not appear to be essentially necessary; for till the moment of being menaced with an attack, many of the garrison of each work will be kept on the watch on the face of the hill, and others be permitted to amuse themselves in its rear. All cooking, &c., is also performed outside of the work, so that it is only at night, or during the action which decides the fate of the position, that the garrisons are closely shut up, and then at least one-third should be kept constantly standing or sitting under arms on the banquette. Besides this, every figure, from the triangle to the circle, varies in the proportion the content bears to the periphery, and it is on the latter only that the defence hinges.

Scarps.—The scarps were formed by cutting the front slopes of ranges of heights near their summit as perpendicularly as the soil or rock of which they were composed could be made to stand, or on such irregularity of level as presented the greatest facility for making a perpendicular cut.

The chief difficulty in tracing a line to be scarped was, to find portions of the ascent sufficiently steep, that when cut to the required angle, the base should not form a road, which might serve as a breathing and rallying point, and unless flanked, a secure communication to an assailant. Fig. No. 90 is a section of a scarp of nearly two miles in length, formed along the summit of the front of the position of Alhandra, in August and September, 1810. Much of the upper 20 or 30 feet of that range of heights was found to be a ledge of precipitous rock only covered with a few feet of earth; which covering being removed and thrown down the face of the hill, the rock behind it was readily made insurmountable to infantry by means of blasting. At other points a species of sandstone, which, when cut through, stood nearly perpendicular, afforded great facility to the formation of the scarps; indeed, without some natural aid, scarping will seldom be found practicable.

It never was presumed that scarps could be trusted to without defenders; but it was considered a great point gained to have rendered portions of ground of such difficult access as to be safely left to the guard of a small corps, or to unsteady troops, such as the militia and ordenanza on the lines. For the purpose of better watching, and to ensure the ready approach of troops and field artillery to all points of the front scarped, a line of interior road was formed nearly parallel to the scarps of Alhandra and Picanceira, at the shortest convenient distance from the front.

Roads and Communications.—The military roads generally were traced along the rear of ranges of heights on the shortest line, concealed from the view of the ground in front; they were perfected during 1811, so as to form a ready communication along the front line from the sea to the Tagus, with direct communications from the rear line.

Several miles of the lateral road were entirely new, as also most of the direct communications from the lateral road to the works; but the intermediate communications between the advanced works and rear line were merely the original car-roads of the country, widened and rendered practicable for military purposes. Many of the communications along the valleys were of necessity paved to keep them in a state to

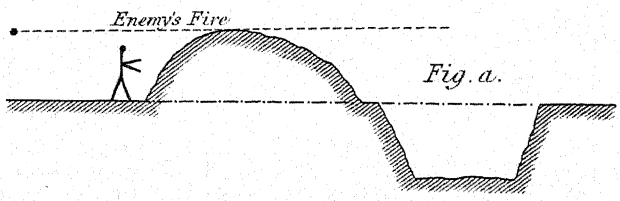


Fig. a.

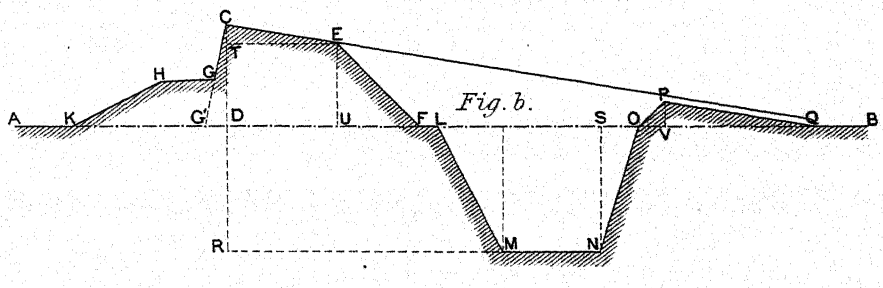
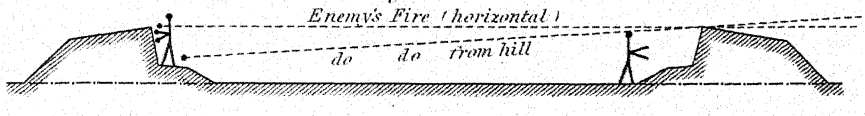


Fig. b.

Fig. c.



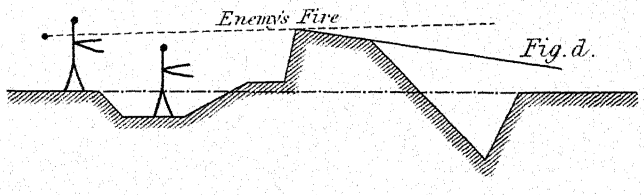


Fig. d.

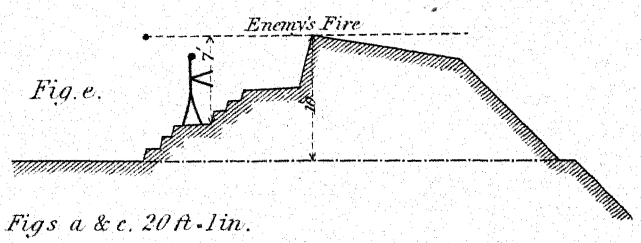


Fig. e.

Scale for Figs a & c. 20 ft-1 in.

" " " b, d, & e, 15 ft-1 in.

" " Fig. f. 60 yds-1 in.

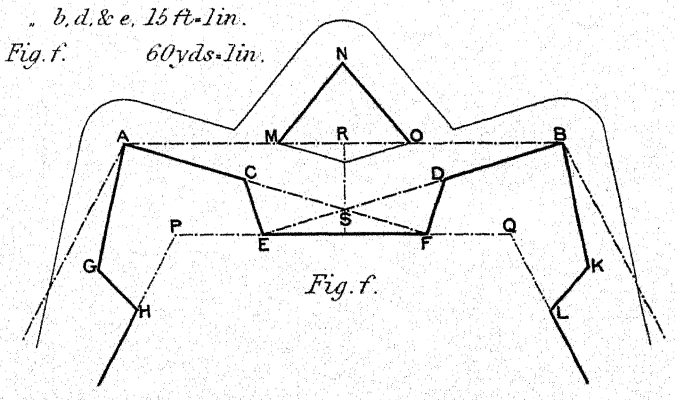
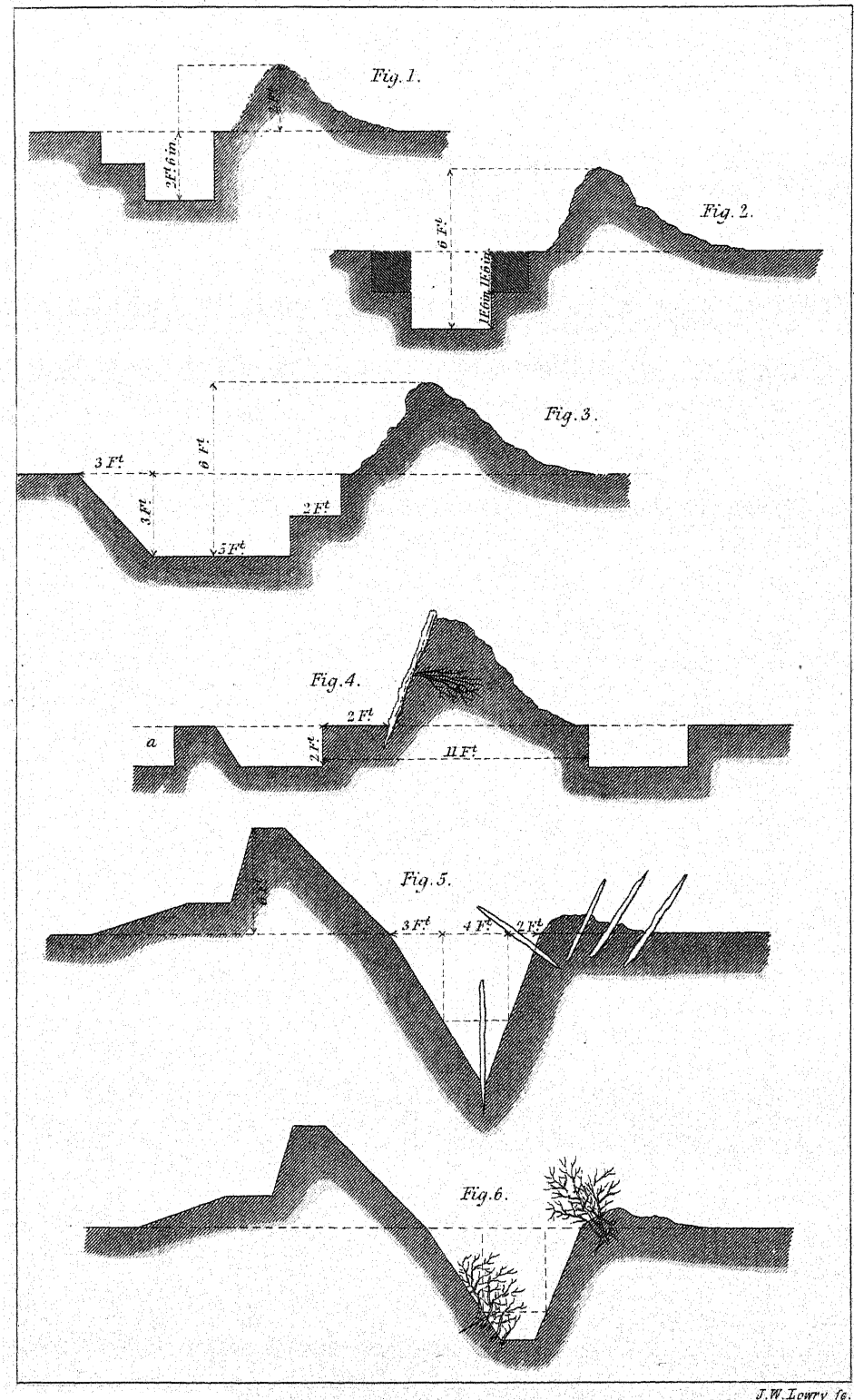


Fig. f.

C. S. H. Capt. R.E. *W. A. Beever, Sc.*

London, John Weale, 1857.



J. W. Lowry fe.

John Weale, 59. High Holborn. 1847.

Fig.7.

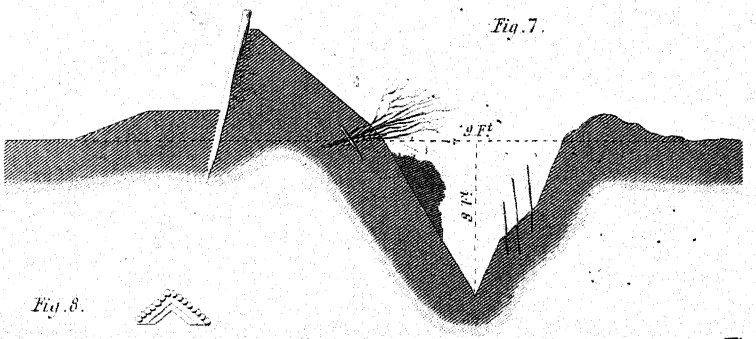
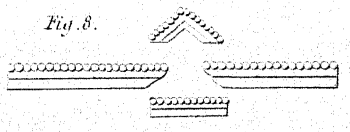


Fig.8.



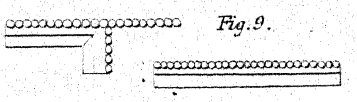


Fig.9.

Fig.10.

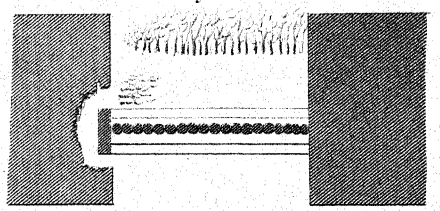


Fig.13.



Fig.11.

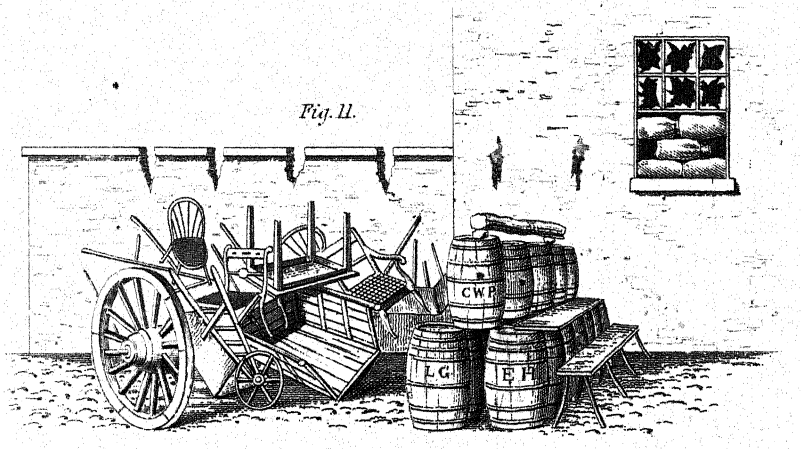
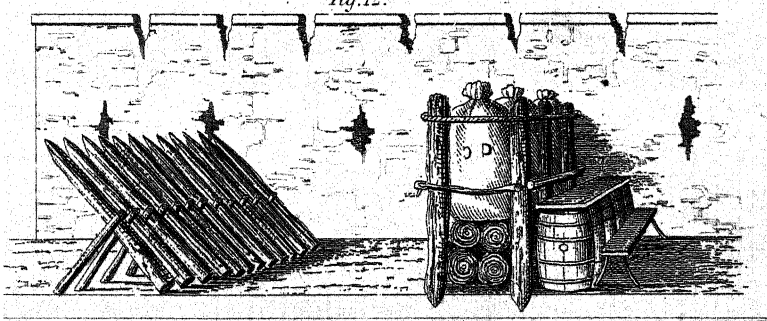


Fig.12.



J.W.Lowry sc.

John Weale 59 High Holborn 1847.

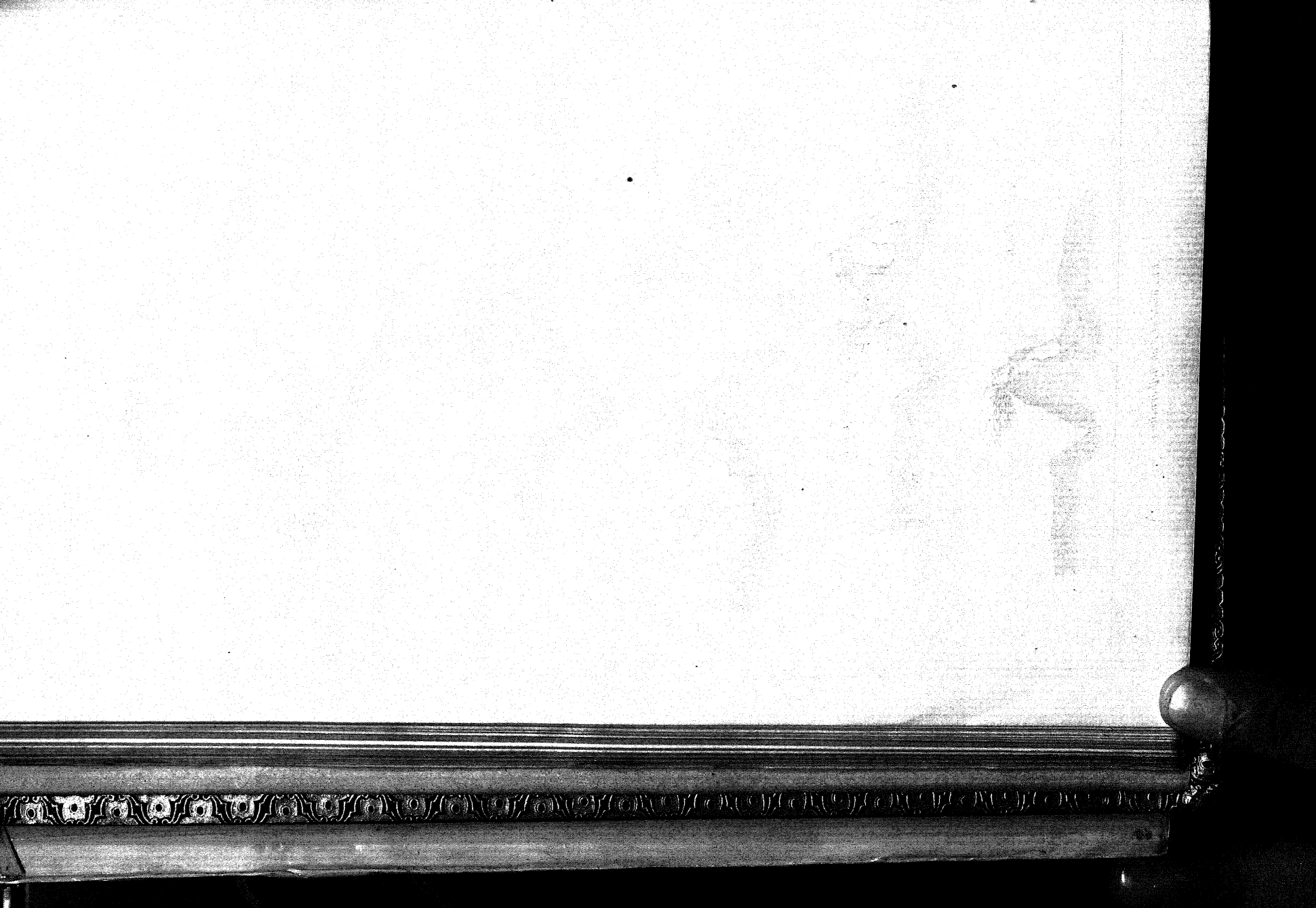


Fig. 14.



Fig. 15.



Fig. 16.



Fig. 17.

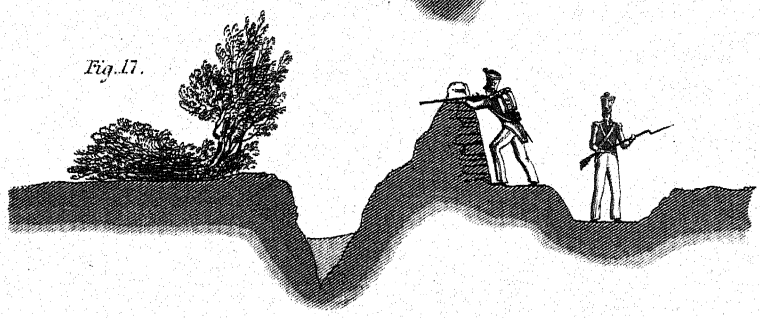
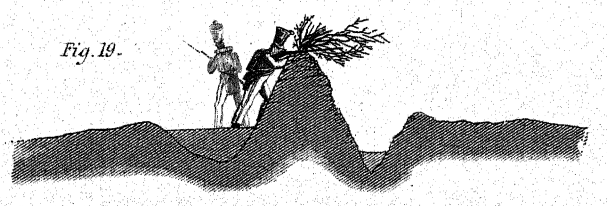


Fig. 18.



Fig. 19.



J.W. Lowry fc.

John Weale, 59, High Holborn, 1847.

Fig. 20.

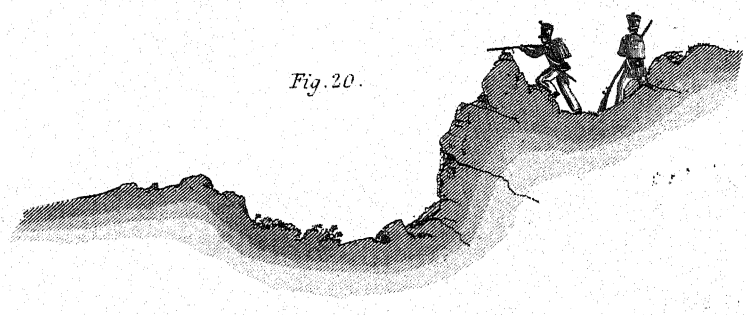
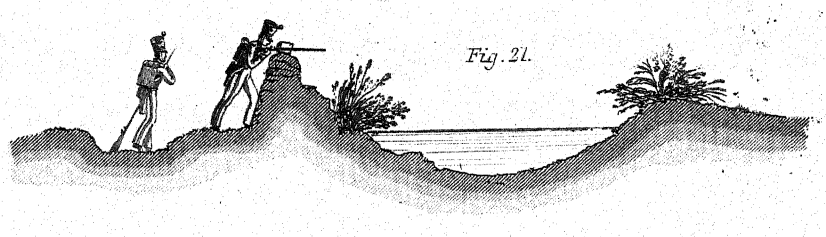


Fig. 21.



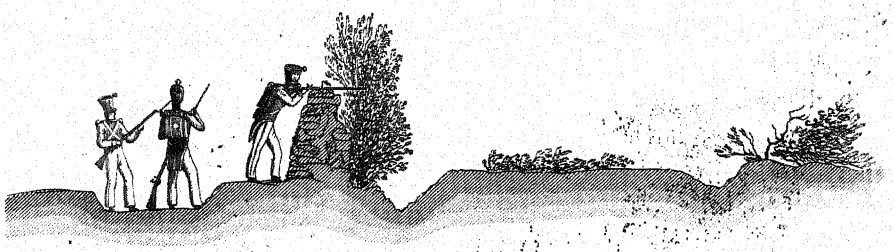
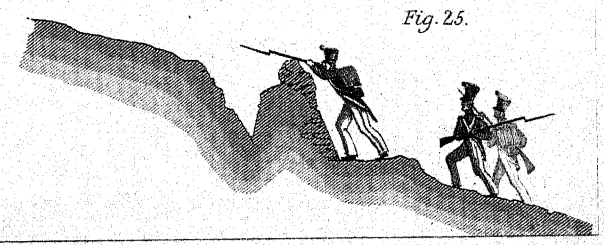




Fig. 24.



Fig. 25.



J.W.Lowry fc

John Weale, 59, High Holborn, 1847.

Fig. 26.

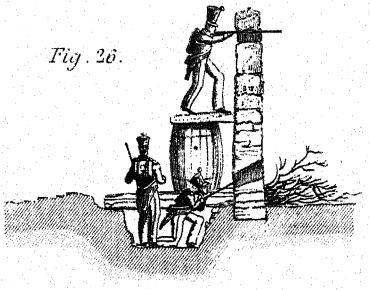


Fig. 27.

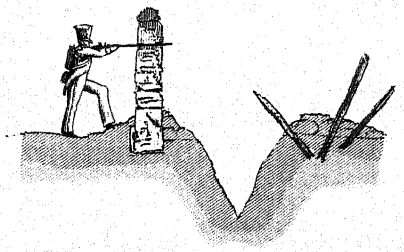


Fig. 28.

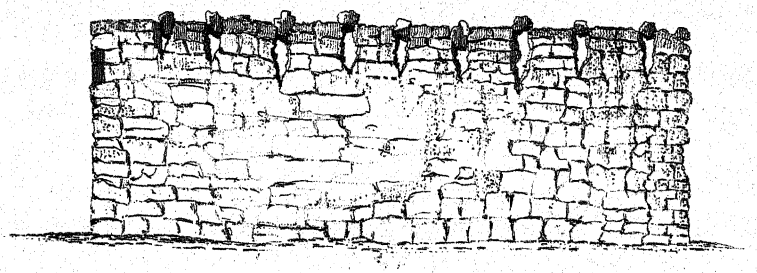


Fig. 30.



Fig. 29.

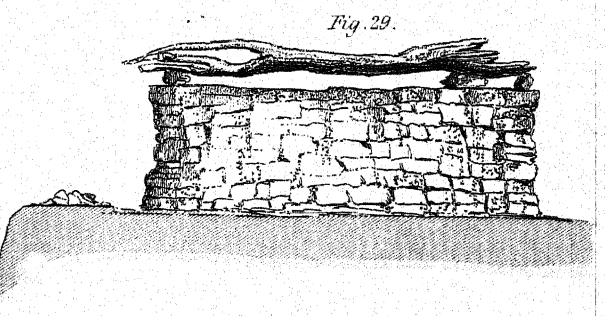


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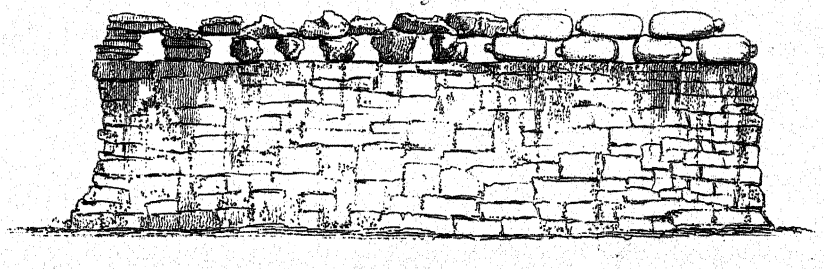
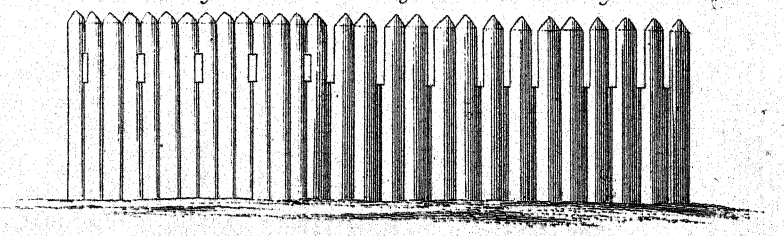


Fig. 32.

Fig. 33.

Fig. 34.



J.W. Lowry fc.

John Weale 59 High Holborn. 1847.

Fig. 35.

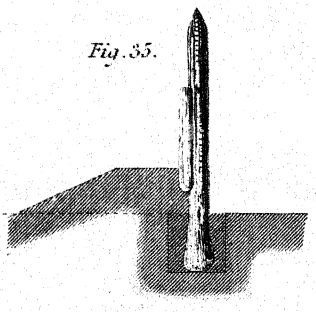


Fig. 36.

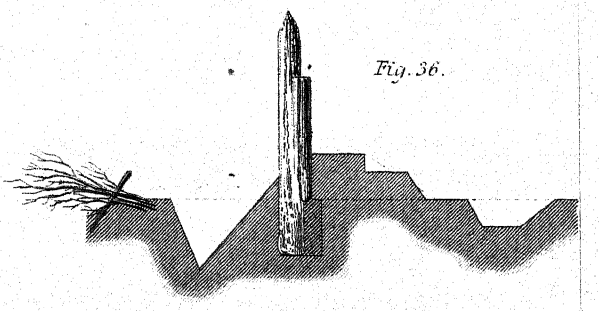


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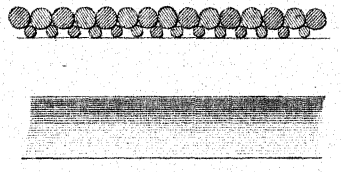


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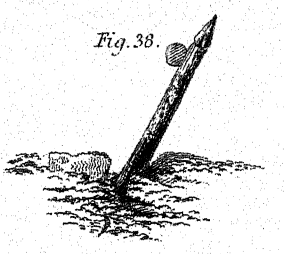


Fig. 39.

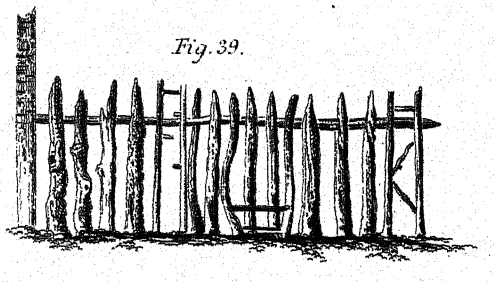
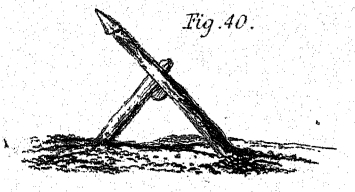


Fig. 40.



Profiles for a Morafs or Swampy Soil

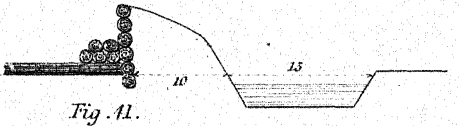


Fig. 41.

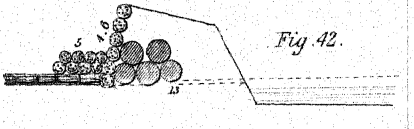
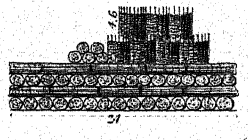


Fig. 42.



Profiles of Epaulements for Cavalry

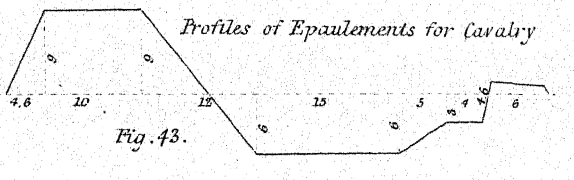


Fig. 43.

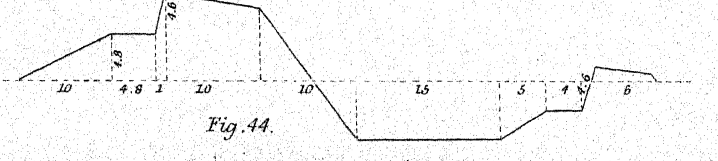


Fig. 44.

J.W. Lowry fc.

John Weale, 59 High Holborn. 1847.

Profiles against Musketry

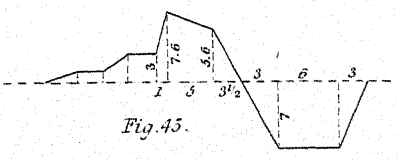


Fig. 45.

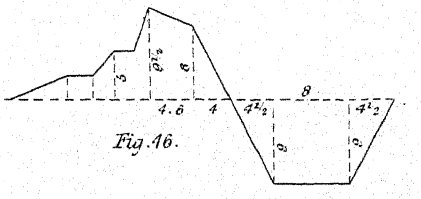


Fig. 46.

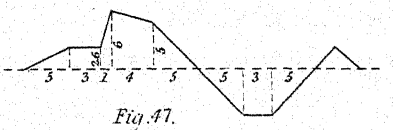


Fig. 47.

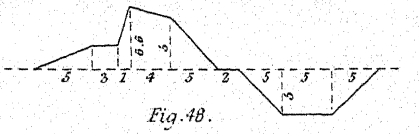


Fig. 48.

Profiles against Artillery

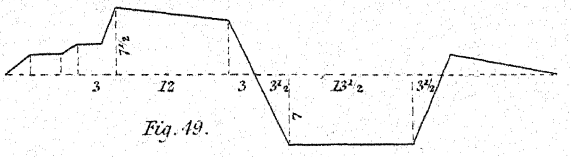


Fig. 49.

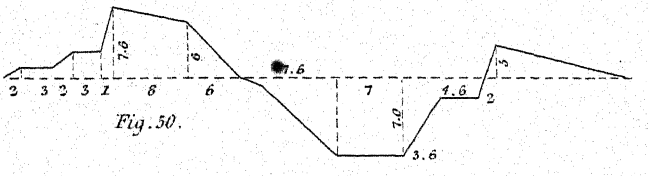


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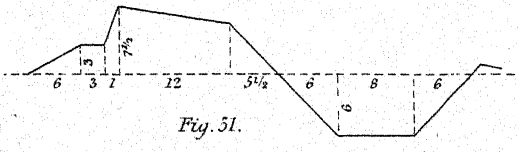


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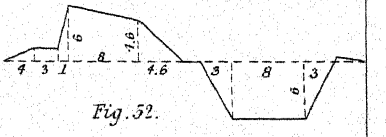


Fig. 52.

Profiles secured by Palisades

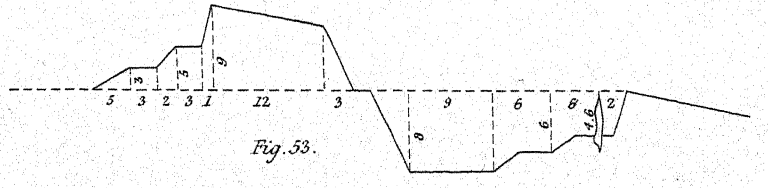
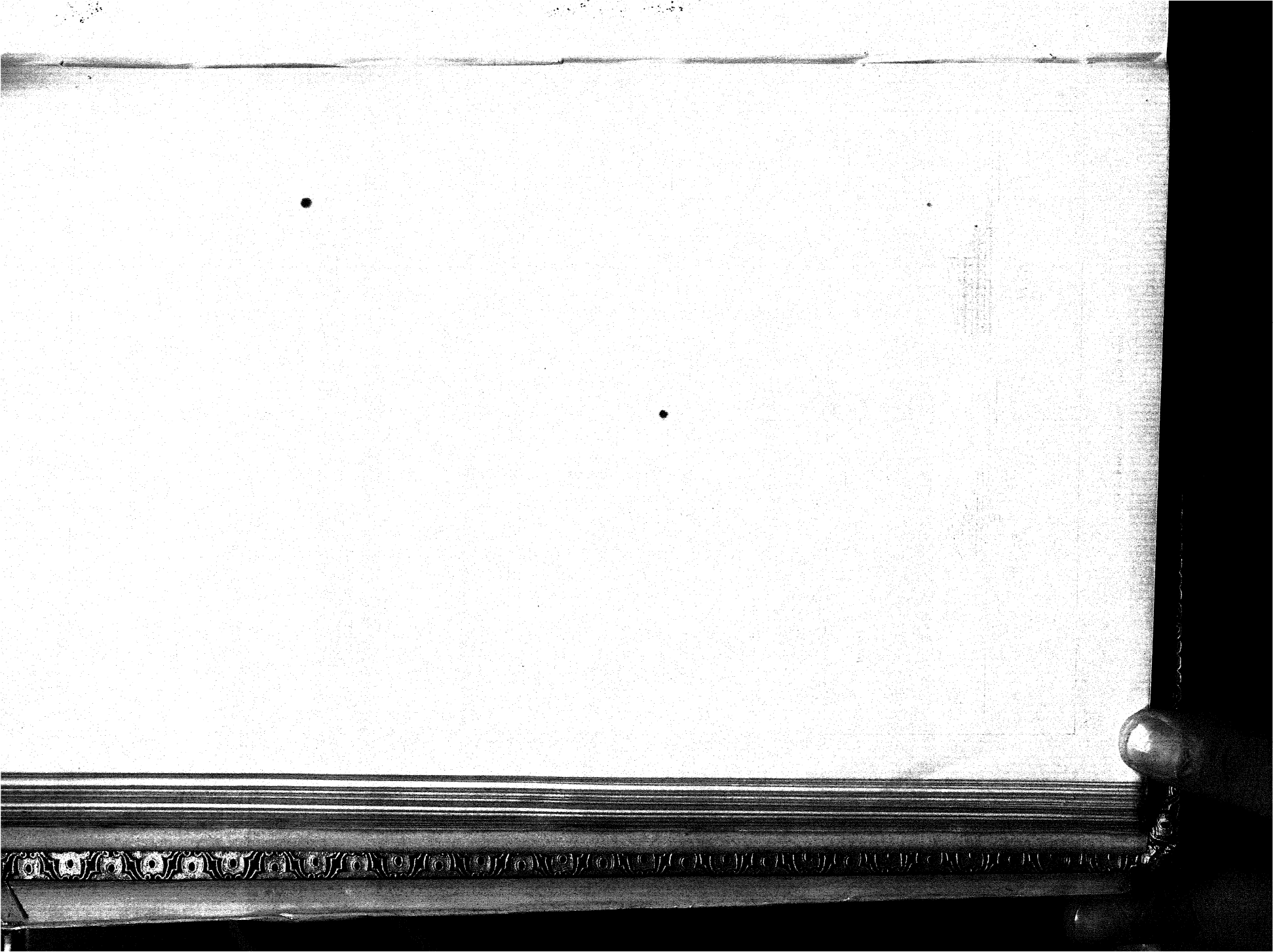


Fig. 53.

J.W. Lowry fc.

John Weale, 59, High Holborn, 1847.



Profiles secured by Palisades

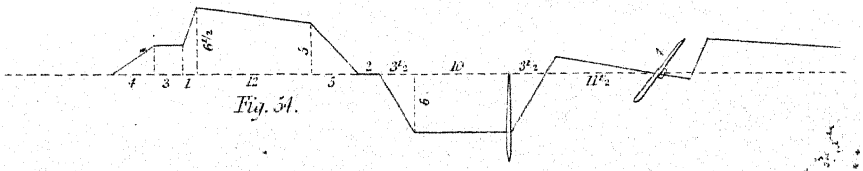


Fig. 54.

Profile secured by Chevaux de frize and Abbatis

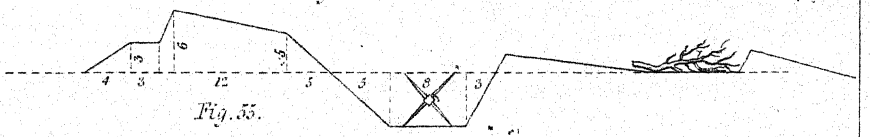


Fig. 55.

Profiles adapted to a Rocky Soil

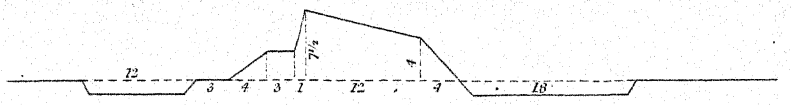


Fig. 56.

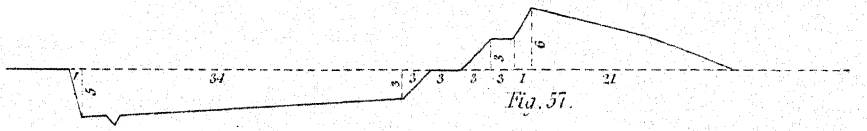


Fig. 57.

Profiles for a Marsh or Swampy Soil.

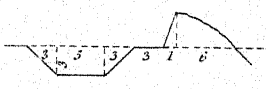


Fig. 58.

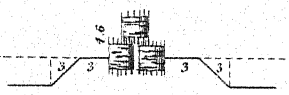


Fig. 59.

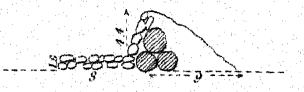


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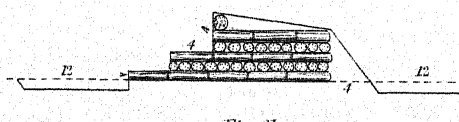


Fig. 61.

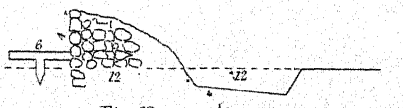


Fig. 62.

J.W. Lowry fc.

John Weale 59 High Holborn. 1847.

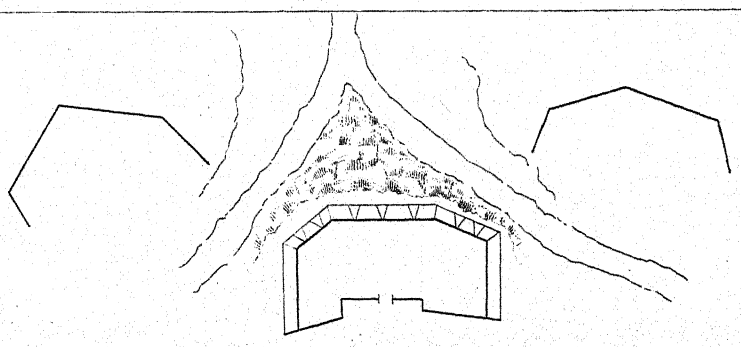


Fig. 63.

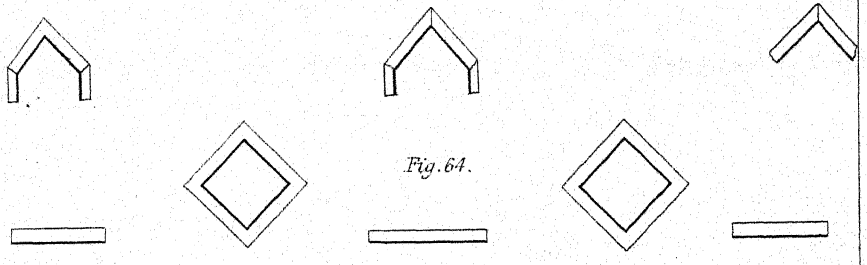


Fig. 64.

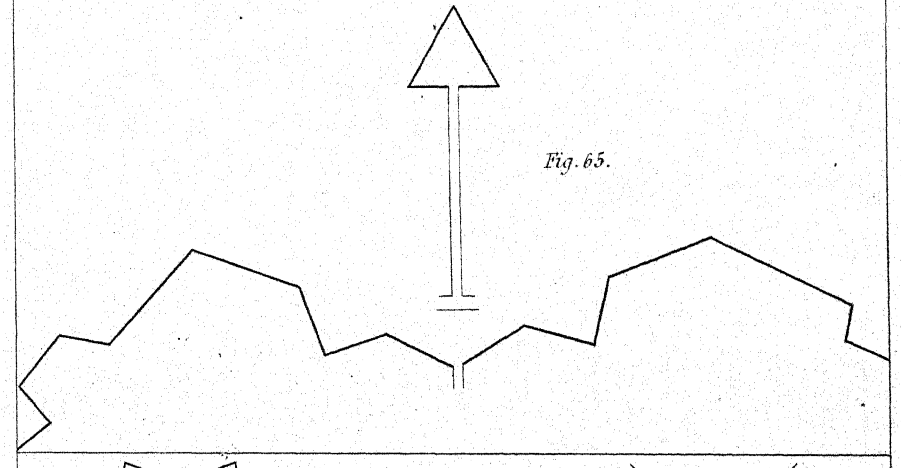


Fig. 65.

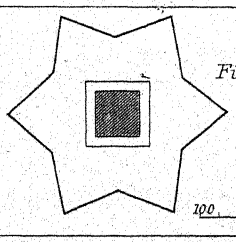


Fig. 66.

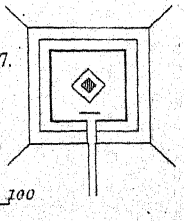


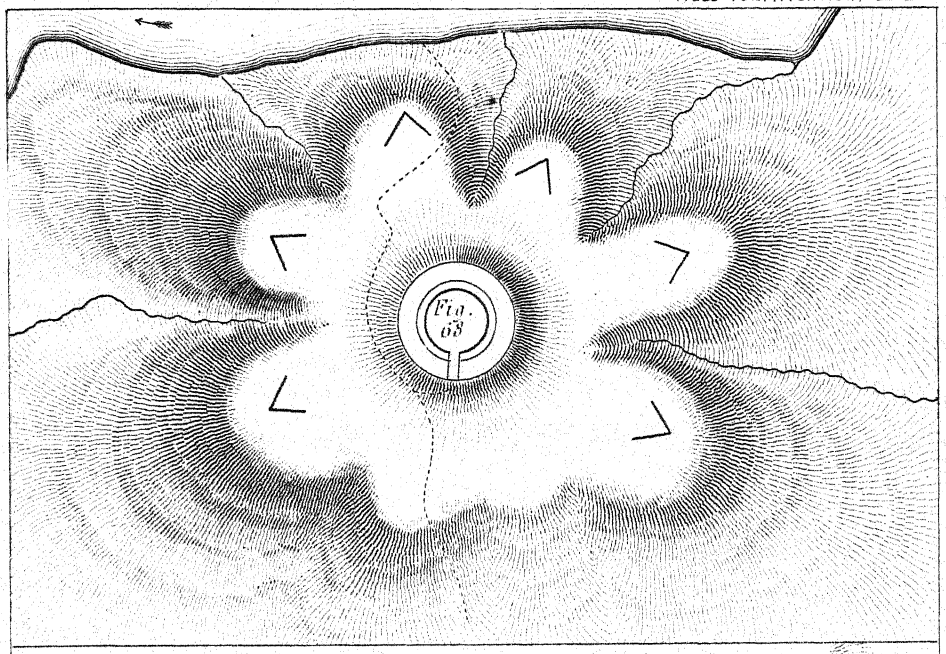
Fig. 67.

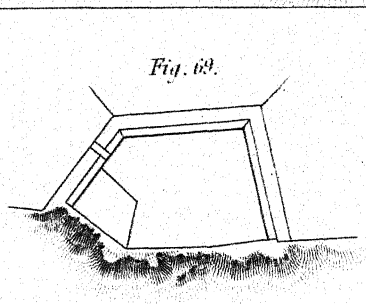
Scale 100 Yards to one Inch.

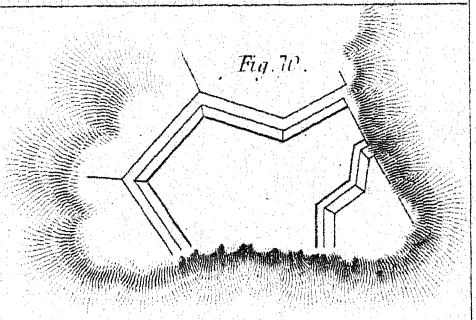
100 50 0 100

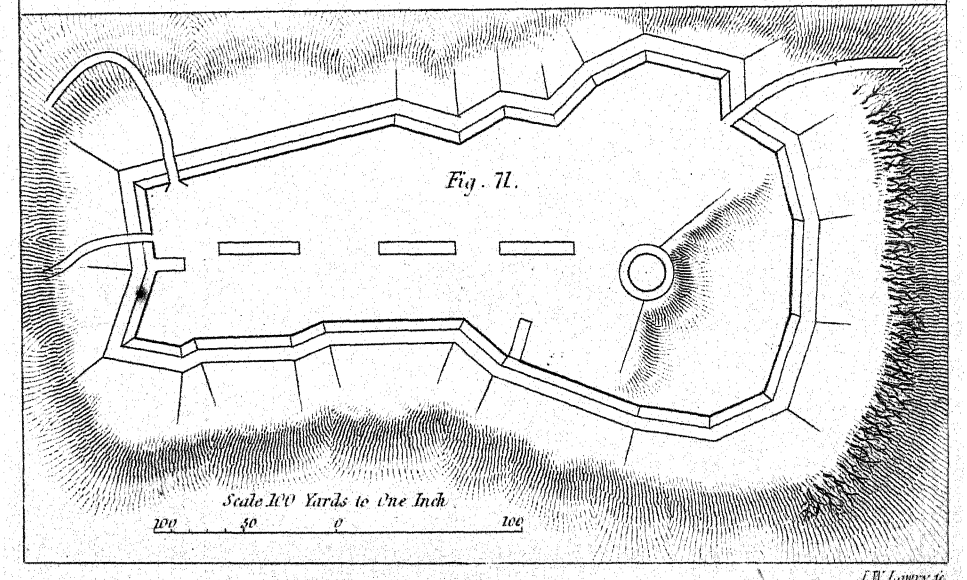
J.W. Lowry fc.

John Weale. 59, High Holborn 1847.




Fig. 69.


Fig. 70.



J.W. Lowry fe.

John Weale, 59 High Holborn, 1847.

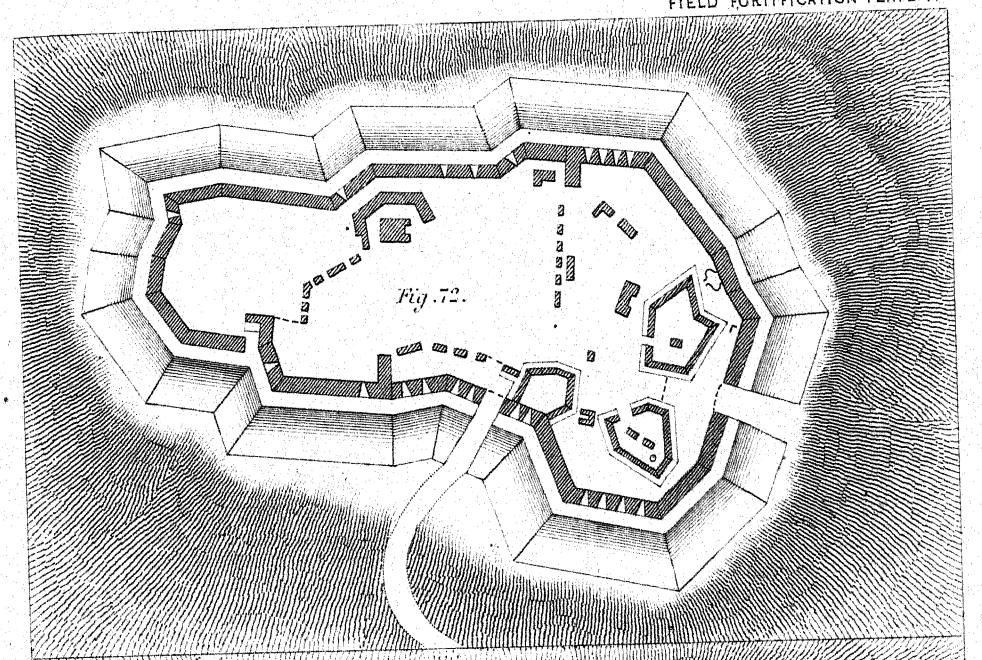


Fig. 72.

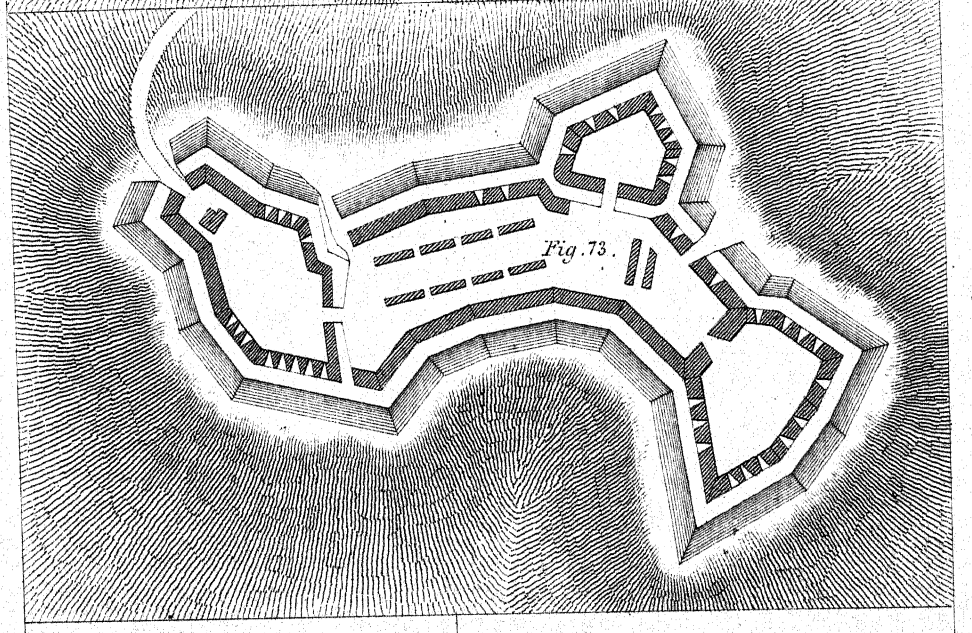


Fig. 73.

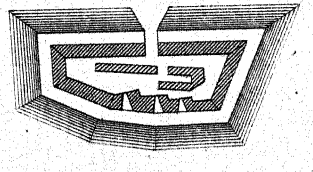


Fig. 74.

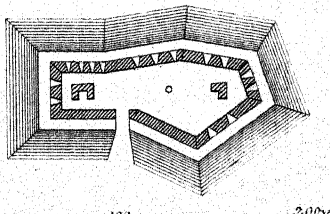


Fig. 75.

400 300 200 100 0 100 200 Yards

J.W. Lowry fc.

John Weale, 59. High Holborn. 1847

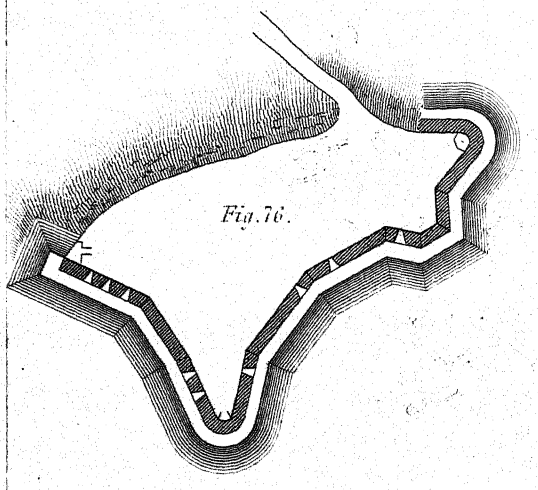


Fig. 76.

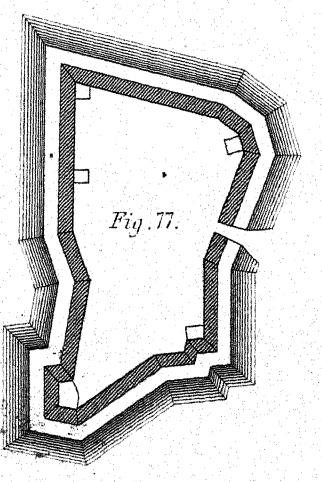


Fig. 77.

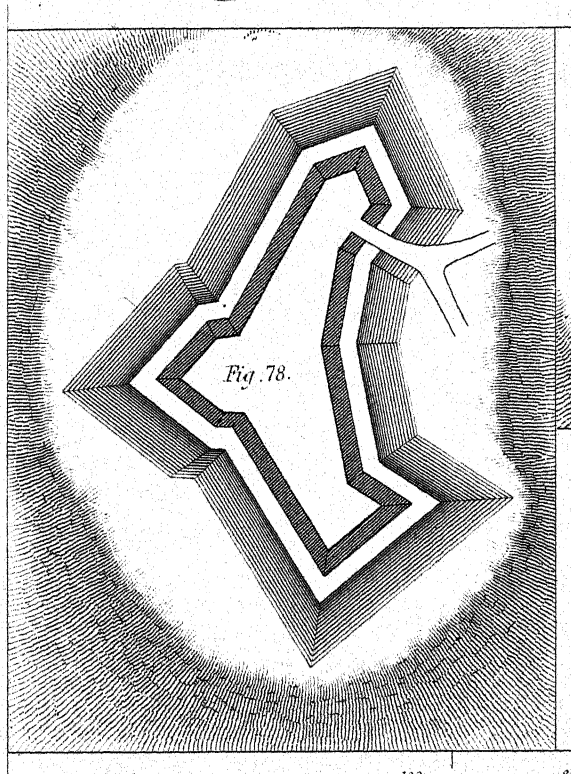


Fig. 78.

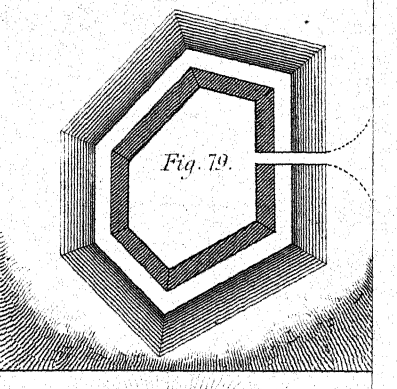


Fig. 79.

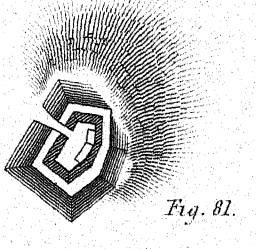


Fig. 81.

400 50 100 200 Yards

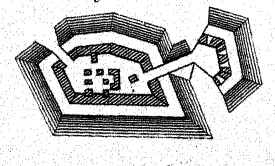


Fig. 80.

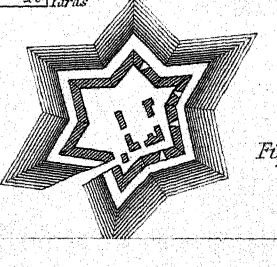
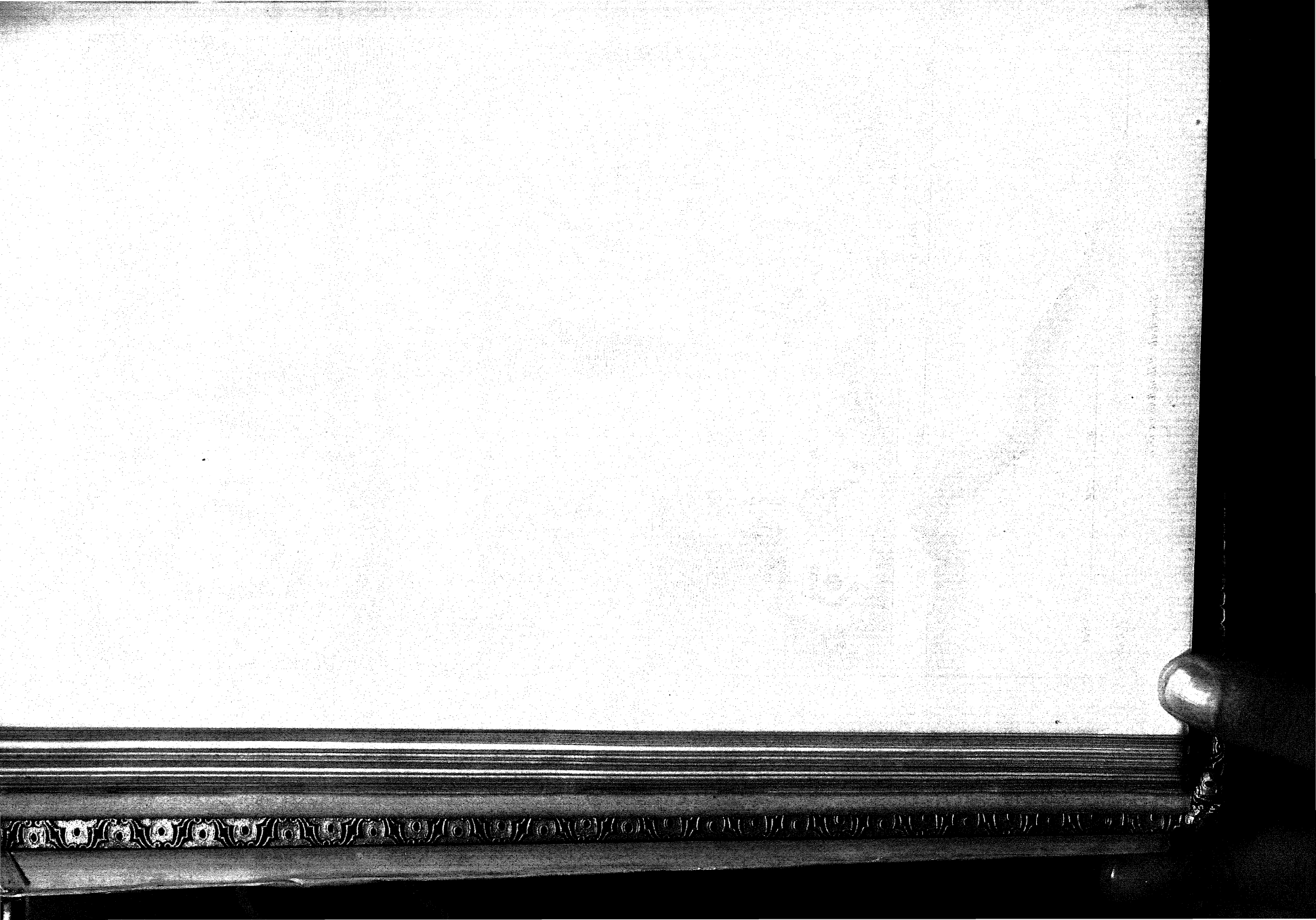
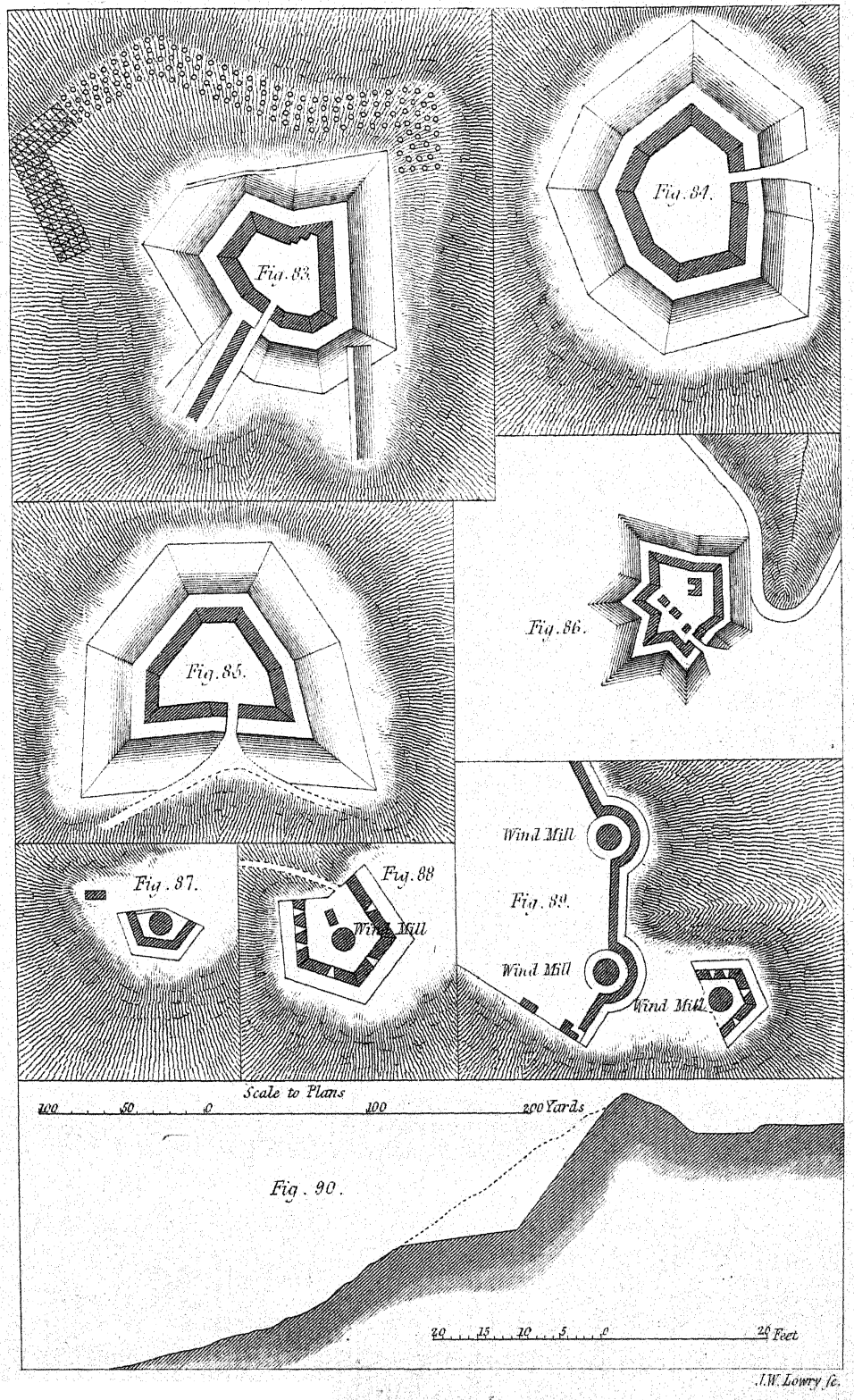


Fig. 82.

J.W. Lowry fe.

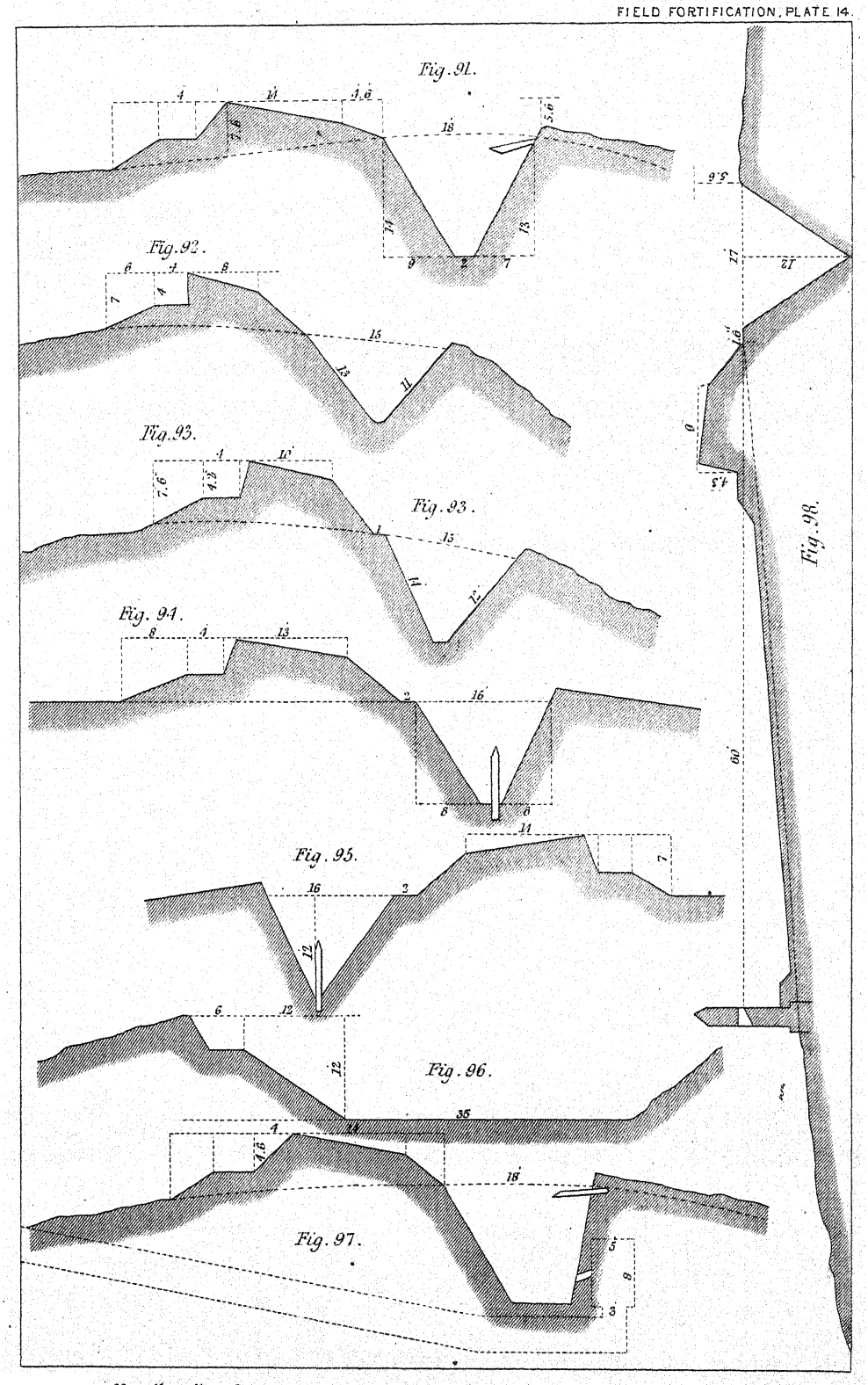
John Weale, 59 High Holborn. 1847.



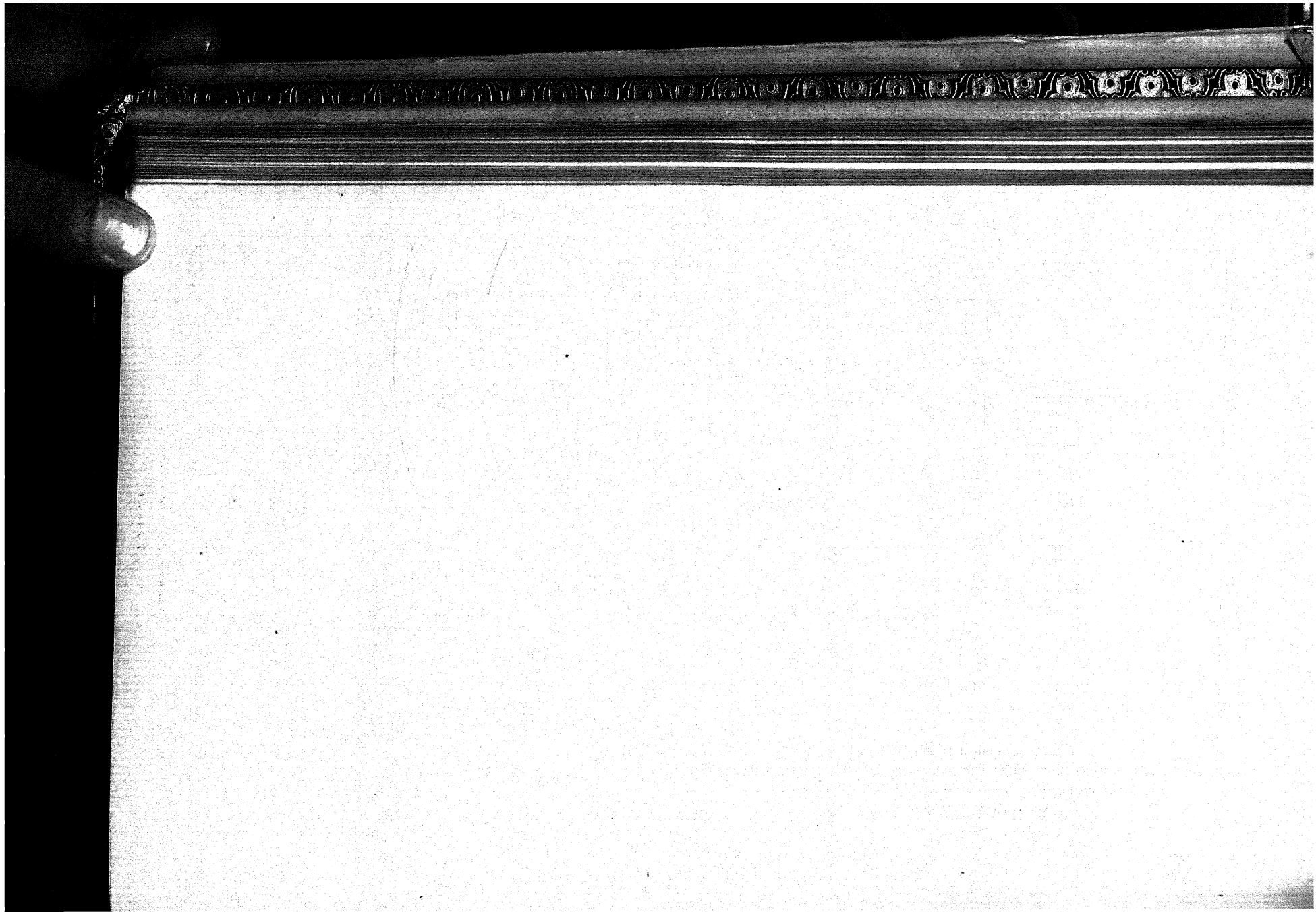


J.W. Lowry fc.

John Weale, 59 High Holborn 1847.



John Weale, 59, High Holborn, 1847.



TRAVERSING PLATFORM

USED IN THE PICKET TOWERS ON THE EASTERN FRONTIER, AT THE CAPE;
FOR A LIGHT BRASS 6 Pr OR 4 2/5 BRASS HOWITZER, OR FOR A 5½ IRON HOWITZER, WHEN NO CRADLE IS REQUIRED.

Fig. 99.

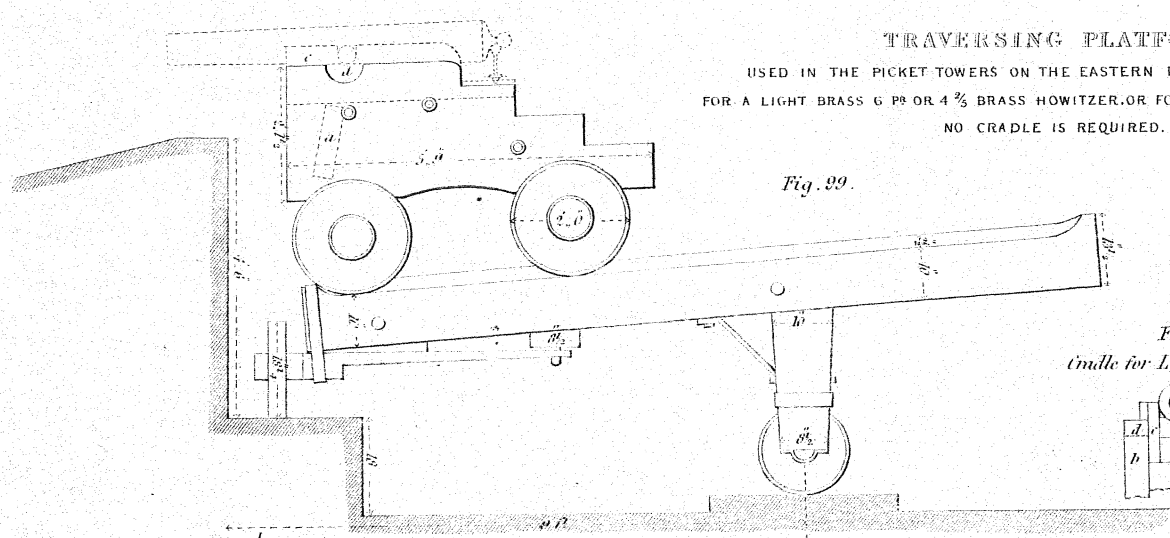


Fig. 100
Cradle for Light Ordnance

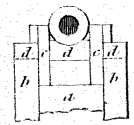
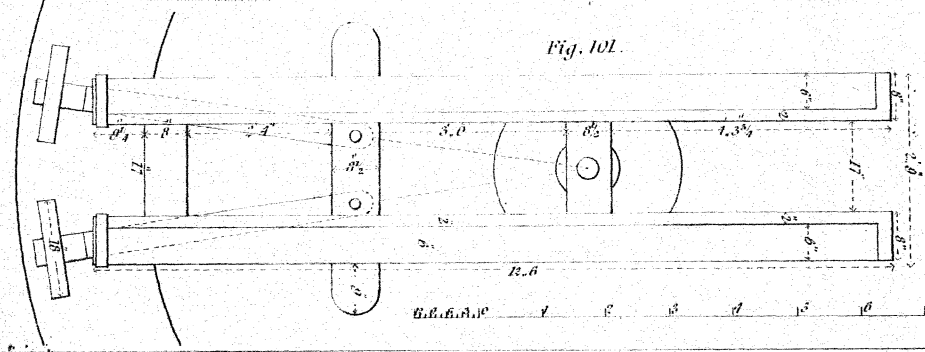


Fig. 101.



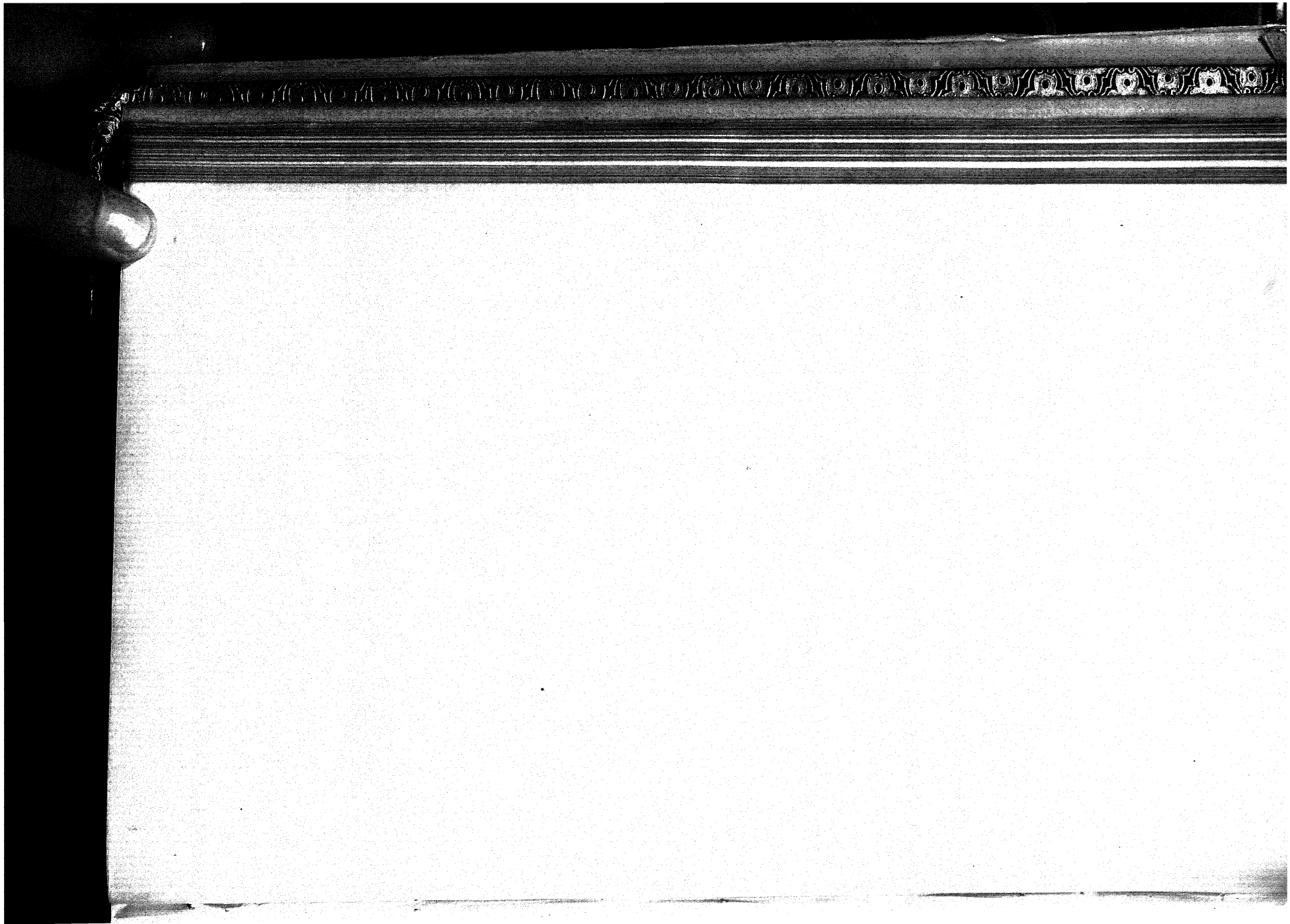
a Transom } *of the Carriage*
b Cheeks }
c Cheeks }
d Wooden Semicylindr. } *of the Cradle*
Trunnion.

0 1 2 3 4 5 6 7 8 9 10 feet

John Weale, 59 High Holborn.

J.W. Lowry, Sc.

FIELD FORTIFICATION PLATE 15.



be used; but generally the heights over which the main communication passed were rocky or abounded with loose stones and other materials which readily formed into firm roads. Fig. 96 is a section of the covered road commenced at Almada, and intended to be carried from the right to the left of that position.

TELEGRAPHS.—The telegraphs were composed of a mast and yard, from which latter balls were suspended; the vocabulary used was that of the Navy, many sentences and short expressions peculiar to the land service being added. These telegraphs readily communicated with each other, at the distance of seven and eight miles; but in consequence of the ranges of hills interrupting the view, it required five principal stations to communicate along the front line, viz. at Alhandra, Monte Agraça, N. S. de Socorra, Torres Vedras, and Redoubt No. 30, in rear of Ponte de Rol.

INTERMEDIATE WORKS.

Before proceeding to the consideration of Permanent Fortification, it may be noticed that there are two classes of works which may be said to occupy an intermediate position; viz. *Places du Moment*, which possess the general character of considerable fortresses, but are in great measure constructed only of earthwork; and *Detached Forts*, which have the general character of Field-works, but are ordinarily constructed of permanent materials, with revetments, &c., and placed in connection with a regular system of Fortification.

FORTRESSES, FIELD, OR PLACES DU MOMENT.*

"*Places du moment*, qui peuvent être construites en terre, dans le courant d'une campagne, n'en sont pas moins réellement des places de guerre."—*Essai Général de Fortification*, livre v. chap. ix.

The judicious emplacement and construction of *places du moment* must be of interest in our Service, as there are so few fortified places in the British dominions. Yet they have all the properties and consequences of fortresses, of which they may be deemed those of the least value. But if we go back to the Peninsular War, subsequent to the publication of the 'Essai Général,' we shall find that the *place du moment*, or *field fortress*, was of great importance; for example, Saragossa, constructed by the Spaniards,—Burgos and Salamanca, by the French,—and Abrantes and Peniche, by the English. Bousmard considers these works under the term of intrenched posts, executed with sufficient care to prevent a coup de main, and to oblige an enemy to go through all the preliminaries, and frequently the whole process, of a regular siege,—in reality, fortresses.

Works of this nature should only be undertaken when there is ample time to execute them with care and solidity, and when local circumstances favour their construction. Among the latter advantages, an old town wall,† large substantial buildings whose walls cannot be destroyed by field artillery, and which can be well secured by blindages,—inundations, escarpments, and abattis, serve as excellent accessories in front, to be connected by substantial redoubts, protected by blockhouses and fougasses.

To render this description of fortress of value, it must be well armed, with at least 12-pounders and 6-inch howitzers and mortars: light traversing platforms should be

* From the Corps Papers, vol. ix.

† "Ce sont ces places du moment, si je peux m'exprimer ainsi, qui ont soutenu les siéges les plus vigoureux, c'est qu'un commandant qui fait réparer une mauvaise enceinte, imaginer les obstacles, les faire naître, les avancer, pour ainsi dire, sur les pas de l'assiégeant."—*Guibert*, '*Essai Général de Tactique*,' second part, chap. xvi.

placed in the salients, and ground platforms in the flanks; expense magazines provided for, with a sufficient supply of water, provisions, and stores.

Places du moment ought to be of sufficient extent to require at least 1800 men, or they become mere field-posts; they are applicable to defensive and offensive operations, where it is obvious what site to choose and what importance it is desirable to give to the works in relation to the object, the number of troops, and provisionment to spare. Regular fortresses are constructed at a vast expense, and the position not always applicable to the circumstances of the moment.

G. G. L.

FORTS, DETACHED.

Usually placed in front of maritime fortresses, to secure the arsenal from bombardment at a distance of from 3000 to 4000 yards: they should be secure against a coup de main, and constructed so as to resist a regular siege, and sufficiently near each other to obtain from artillery a cross as well as a collateral fire. *Detached Forts* should also be placed at the principal points which command the anchorages, to prevent a bombardment from the sea; and the body of the place, or *enceinte*, in rear of them, may be either a simple loopholed wall, à la Carnot, or rampart, ditch, and covert-way, with or without outworks, according to the importance of the fortress and the means of relieving it.

Detached Forts have lately been placed from 800 to 1200 yards in front of strategetical fortresses, as at Paris, Lyons, Mayence, and Cologne.

In the description of the *German System of Fortification*, by General Brèze, a minute detail is given of the advantages of this mode of fortifying places, as explained in Plates I. and III.: in all cases detached forts should be flanked all round.

The figures in the Plate of Detached Forts explain the French system, as adopted at Paris and Lyons.

Fig. 1 represents some connecting forts around the village of St. Denis, which protect each other by a collateral fire; the intermediate ground to be inundated. Their fronts vary from 328 to 527 yards, and they are in advance of the *enceinte continue* about 1100 yards.

Fig. 2 forms part of a range of forts to cover Lyons on the left bank of the Rhone, which are constructed in low ground. *Fort des Breteaux* has three fronts of 284 yards, with a gorge of 437 yards: the latter contains the barrack and magazine. The interior redoubt is quadrilateral, with escarpes detachées, with loopholes and machicoulis (see Plate VII. of the Bastion system), and the terreplein of the fort forms the ditch of the redoubt.

Lunette des Charpennes is revetted and casemated throughout and loopholed, with a dry ditch and glacis, and an advanced wet ditch. This work sees the reverse of the *Forts des Breteaux* and *Tête d'Or*, which constitutes the peculiar nature of this lunette.

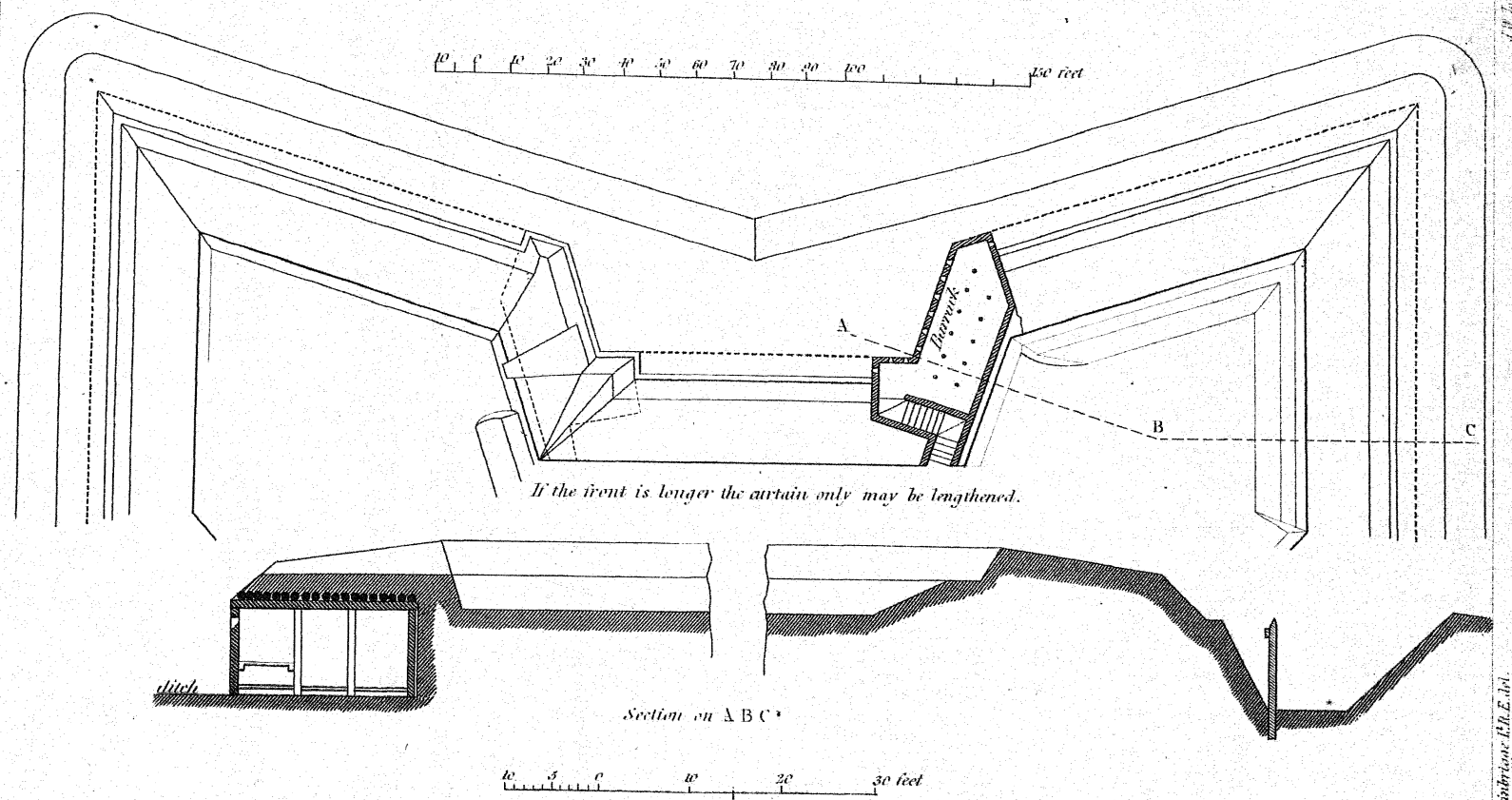
Fort de la Tête d'Or is a kind of bonnet de prêtre, with very obtuse angles, flanked by bastionets* (see Plate VII. of the Bastion system). This fort is revetted by a detached escarp with a chemin des rondes; and the middle of the gorge is occupied by a defensible barrack, which is bomb-proof and loopholed.

Fig. 3.—*Fort de Sainte Foy* is a quadrilateral of which two sides are bastions, fronts from 219 to 361 yards in length: the escarps and counterscarps are revetted, and the parapets of the bastions have batteries à l'Haxo, as explained in Plates VI. and VII. of the Bastion system. This fort is built upon elevated ground.

* A caponière at the salient angle instead of the re-entering, as adopted in the German system.

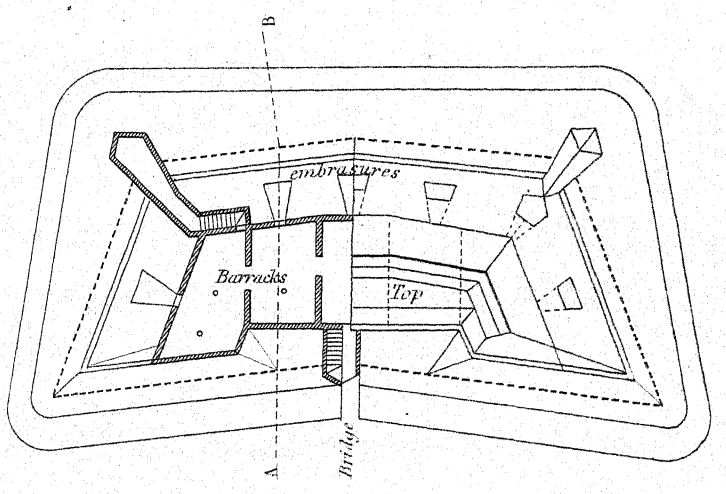
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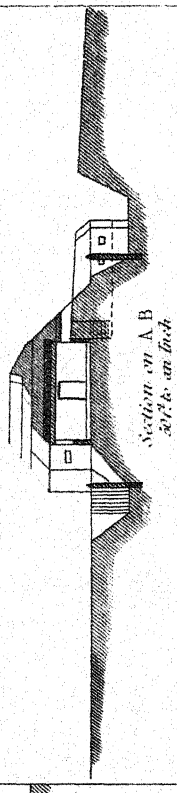
FIELD FORT PL. 2.



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Fig. 1.

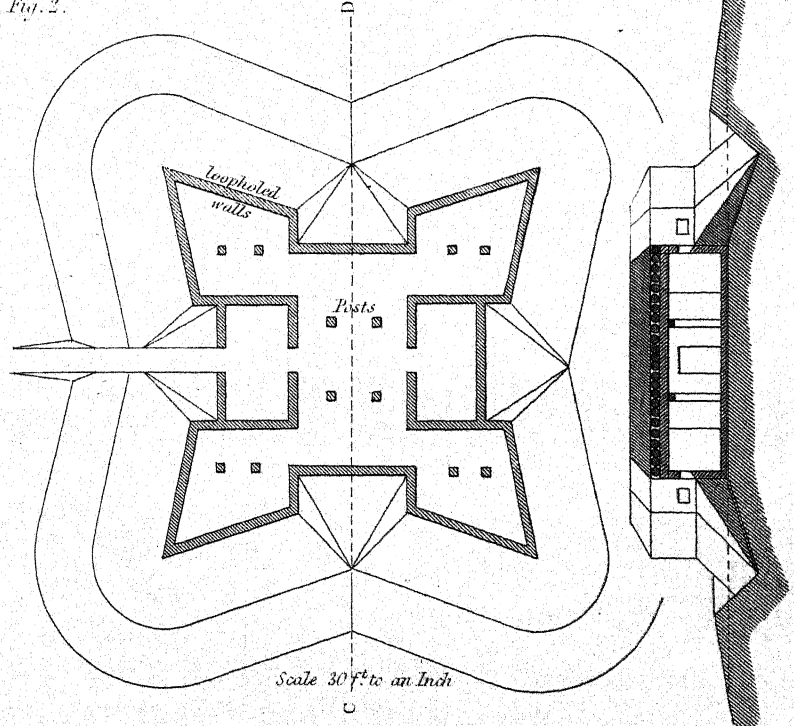


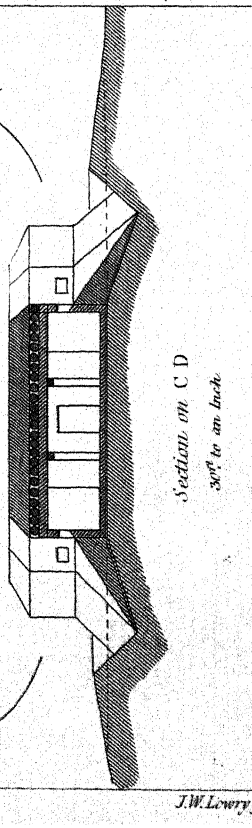


The outer thick dotted lines represent Palisades
The shaded parts shew the walls (of wood or stone)

Scale 30 ft to an Inch

Fig. 2.

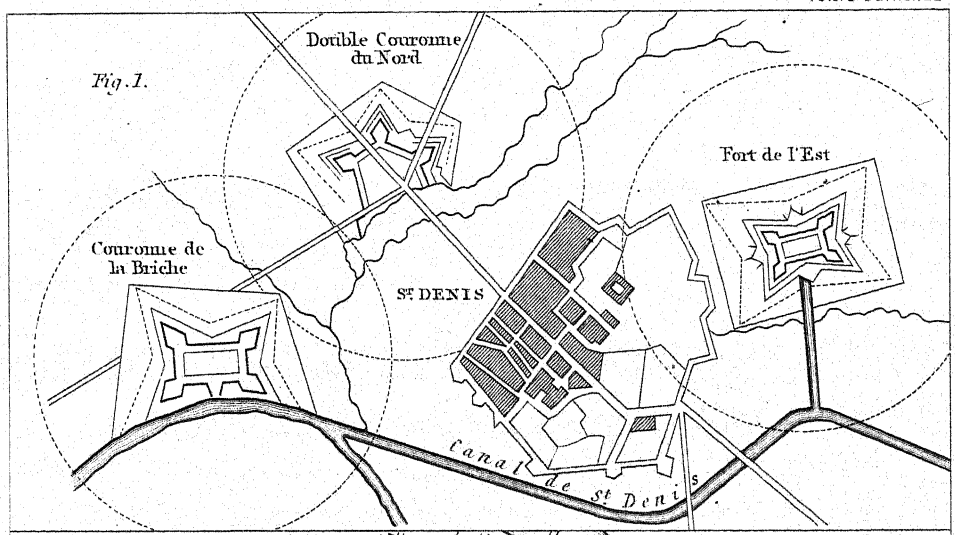


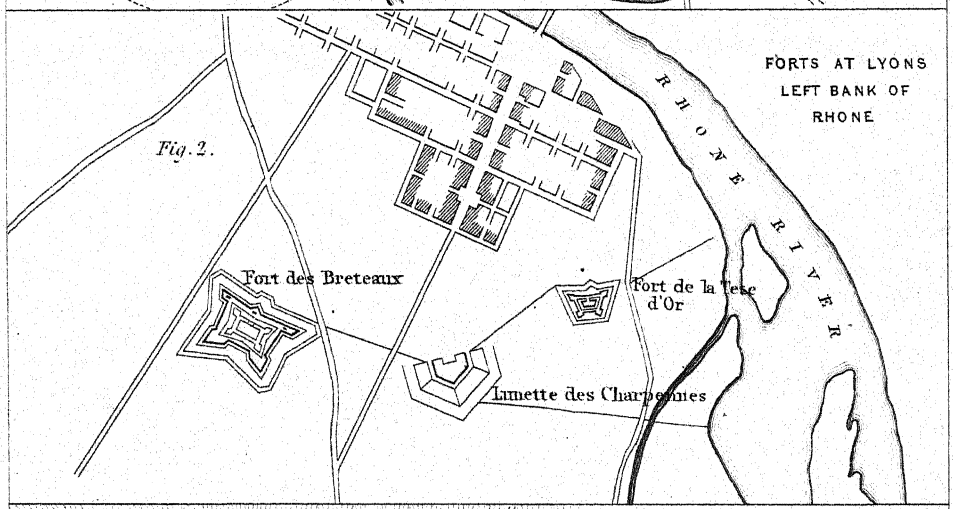


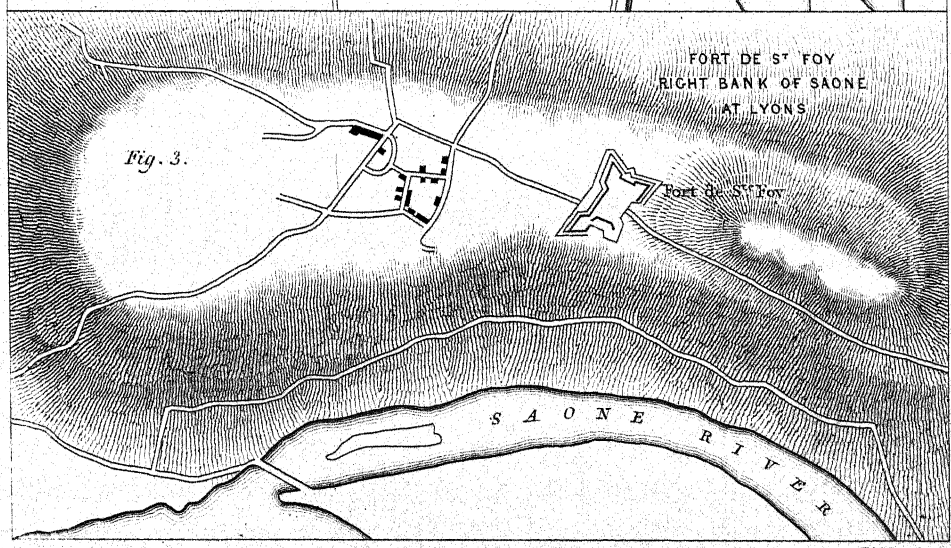
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P. Bainbridge Lt. R.E. del. *J.W. Lowry fc.*

John Weale, 59 High Holborn.







John Weale 39 High Holborn. 1847.

One observation is necessary in conclusion, which appears to be omitted by most of the advocates of fortifying with detached works, however applicable they may be to circumstances,—that they want the homogeneous character of a fortress; and it is conceived that eight detached forts can never be equal to an octagon of a similar construction.

The division of the force, resources, and responsibilities, all tend to weaken the value of detached forts, except in advance of a fortress of some strength.

Advanced Forts, placed beyond the covert-way within musketry fire, must be considered distinct from those called detached, such as lunettes à la Darçon, and other works open at the gorge: they should however, if possible, be countermined, and secure from a coup de main. G. G. L.

PERMANENT FORTIFICATIONS.

As mentioned in the preliminary remarks on Fortification, page 1, the great principles of defence always remain the same; it is only the degree to which these principles can be carried out that constitutes the difference between Permanent and Field Fortification. These principles will not therefore be recapitulated, but some observations will first be made upon the simplest methods by which they are put in practice in permanent works; and the different systems of Fortification employed or recommended by some of the most celebrated engineers, will then be treated of.

PART I.—SECTION I.

Profile.—The great difference in Profile between a permanent and a field work, is the increase of the command of the parapet and of the depth of ditch. The former of these enables the defenders to have a better view of the surrounding country, and also to interpose other works in connection with the main work, between themselves and a besieging army; the latter offers an increased obstacle to assault.

Rampart.—The increased command over the country is usually obtained by raising the parapet on a mass of earth called a rampart. Its upper surface or terreplein is ordinarily made about 40 feet wide, measured from the interior crest, and allows ample room for the working of heavy guns, and for the passage of carts, etc. behind them. Its interior is usually left at the natural slope of the ground, along which Ramps are made at convenient intervals; this slope is in some cases replaced by a wall.

Scarp Walls.—Along the front of the rampart and extending to the bottom of the ditch, a wall, of which there are various forms in use, is generally built. This wall should be for important works at least 30 feet high, as a less height would not offer security against escalade.

The different forms of Scarp Walls or Revetments are as follows:—

1. The Full Revetment (see Permanent Fortification, Pl. I. fig. 1), in which the wall runs up to meet the superior slope of the parapet.

2. The Demi-revetment (fig. 2), which is generally carried a few feet above the level of the country.

3. The Chemin des rondes Revetment (fig. 3), in which the wall is separated from the parapet by a small space, permitting a passage between it and the exterior slope, and is provided with a banquette for musketry fire. Its top, as in the demi-revetment, is usually a few feet above the level of the country.

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* By Captain C. S. Hutchinson, R. E.

4. The Independent Scarp, or Carnot's Wall (fig. 4), which is altogether detached from the parapet, the exterior slope being carried down nearly to the level of the bottom of the ditch. It is usually loopholed near the bottom, the loopholes being formed in recesses.

Counterforts.—It is customary to add counterforts of various forms (*a*, *a*, *a*, figs. 1, 2, 3) behind scarp walls. These give increased stability to the wall by their weight; impede, by friction upon their rough sides, the pressure of the earth against the back of the wall; and also render more difficult the formation of breaches. Their form on plan is either rectangular, dovetailed, or diminished (fig. 5 *a*, *b*, *c*), and they are placed at intervals of from 16 to 20 feet; their length being from 5 to 8 feet, and their thickness from 4 to 6 feet. By their use the thickness of the wall may be much diminished, and if arches are turned between them, as shown in fig. 6, the formation of breaches becomes an exceedingly difficult operation, owing to the small quantity of earth that would follow the fall of the wall until the counterforts or arches were destroyed. In some positions the chambers formed between the counterforts may be converted into galleries for musketry fire, the wall being loopholed.

Comparison of the different Scarp Walls.—In comparing together these different forms of wall, adapted to parapets of the same relief, it will be readily perceived that—

1st. As an obstacle to escalade (when uninjured), the detached revetment is most formidable, from the fact of the besieger having, when mounted on the top of the wall, to reverse his ladders, an operation which may well be considered desperate in the face of a vigorous resistance. The full revetment, on account of its great comparative height, ranks next in the scale of difficulty, as also because the besiegers are exposed to the direct fire of the parapet at the instant when their heads appear above the wall.

Next comes the Chemin des rondes Revetment, which, though much lower than the full, enables the garrison to lay hold of the ladders and upset them, and also to bayonet the enemy as they reach the top of the wall.

The Demi-revetment offers the least impediment to escalade, from being low, and from the enemy being able to assemble at the foot of the exterior slope, unseen by the direct fire of the parapet.

2nd. As regards security against breaching by distant fire, the Demi-revetment ranks first, being generally entirely or nearly screened from an enemy's view by the crest of the glacis, and being too substantial to be much injured by a pitching fire, in which, as in ricochet, the shot necessarily have but small momentum.

Next in merit stands the Chemin des rondes, which, though it may be screened from an enemy's view, is liable to have its upper part destroyed by pitching fire, not however entailing the fall of any part of the parapet.

The full and detached Revetments both present great defects as regards breaching by distant fire. The former can be seen for a considerable portion of its height above the crest of the glacis, and is therefore exposed to fire with full charges, which would breach the part exposed; causing, in most cases, the fall of the crest of the parapet, or at all events so reducing its thickness as to render the interior of the work no longer secure.

The detached Revetment can, though entirely screened from an enemy's view, be breached to its very foot by distant pitching fire, as proved by the experiments made at Woolwich in 1822. This of course exposes the work to the chances of successful assault, without the necessity of escalade.

3rd. With regard to the formation of practicable breaches from batteries on the glacis, the relative degrees of difficulty would be as follows:—

1. Chemin des rondes revetment.
2. Demi revetment.
3. Detached revetment.
4. Full revetment.

As may be readily seen on reference to figs. 1, 2, 3, 4, where the wall is supposed in each case to be breached to the same level above the bottom of the ditch, and the earth supposed to separate at an angle of 45°.

4th. As regards economy of space, the order of advantage follows that of the figures, as is evident on inspection. Besides the differences of form already explained, revetment walls may be either countersloping (fig. 1), sloping (fig. 3), leaning (fig. 2), or rectangular (fig. 6). The sloping revetment ensures the greatest amount of stability with the least expenditure of material, but is more liable to decay, from the growth of vegetation in the joints of the masonry, and is more favourable to escalade than the countersloping revetment, the use of which would therefore, in most cases, appear preferable. When the spaces between the counterforts are arched over, and the pressure of earth upon the back of the wall thus removed, rectangular revetments might of course be employed.

Fig. 7 shows what may be the profile of a permanent work with a demi-revetment under ordinary circumstances.

Covert-way.

Covert-way.—Between the counterscarp and crest of glacis a space called the "Covert-way" is usually left; the glacis forms its parapet, and it is provided with a banquette for musketry. It is commonly made about 11 yards wide from crest of glacis to top of counterscarp, which affords room for all the operations of the defence, and yet is not sufficient to allow of an enemy forming a battery on its terreplein.

The counterscarp is usually either wholly or partially revetted with masonry, except in the case of a wet ditch, where it might be wholly of earth. The covert-way is a work causing little expense, and is of great utility. It enables the garrison to post sentries on the further side of the ditch, thus guarding against surprise; it facilitates the execution of sorties; it permits of a galling and destructive fire of musketry being directed on the besiegers when they arrive near the place, and also aids the admission of reinforcements and supplies into the fortress.

The musketry fire from the main work should defend the interior of the covered way, and to do this should pass within at least 4 feet of the edge of the counterscarp.

Glacis.—The Glacis, which forms the parapet of the covert-way, is usually given a command of 7′ or 8′ above the country, its outer surface having a gentle slope to the front, so as to allow of its being swept by the artillery fire of the main work. Hence, the more distant is the crest of the main work and the less its command over the crest of the glacis, the more gentle should be the slope of the latter. The minimum limit to this slope is determined by the consideration that the besiegers' lodgments would, if it were made too gradual, command the crest of the glacis when still at a considerable distance from it; and also that the more gentle the slope, the greater is the difficulty of applying it to irregularities of ground. For these reasons it has been considered advisable never to give it a less inclination than 1 in 30.

Construction of Profile.—The following then are the conditions which it is desirable to adopt in constructing the profile of any permanent work:—

1st. The scarp wall should be covered by the glacis to as great an extent as possible from the view of an enemy situated on the most commanding point in the neighbourhood within breaching distance. (This of course is possible in the case of a full revetment, only when the work is situated on an eminence, with no equally high ground in its neighbourhood.)

2nd. The musketry fire from the parapet of the main work should defend the covered way.

3rd. The glacis should be swept throughout by a fire of artillery from the main work.

Supposing then that the greatest admissible depression of musketry fire is $\frac{1}{6}$, and that the artillery fire proceeds from guns mounted on garrison carriages, which, with parapets 8 feet high, would raise the muzzles to within about 5′ 9″ of the crest, in order that conditions Nos. 2 and 3 may be fulfilled, the crest of the work must not be below a plane passing parallel to and 5′ 9″ above the slope of the glacis, nor above a plane having an inclination downward of $\frac{1}{6}$, and passing not more than 4 feet above the edge of the counterscarp.

It may hence be readily seen that the slope of the glacis and width of the ditch are mutually dependent on each other. If circumstances require the use of a narrow ditch, and consequently a low command (in order to secure musketry defence to the covert-way), a gently sloping glacis will be the result: on the contrary, a steep glacis produces a high command, and a wide ditch becomes therefore necessary, in order that condition No. 2 may be fulfilled. In case a steep glacis and narrow ditch are both required, it will be impossible to fulfil both the 2nd and 3rd conditions; and in ordinary cases it is most important to defend the covert-way, which has no other defence, while the glacis is usually flanked by some other work.

Another point to be attended to is, that if the enemy can establish himself upon ground within range of and commanding the crests of the glacis and main work, the terrepleins of the covered way and rampart should be defiladed, or made parallel to planes passing through that ground and the respective crests.

SECTION II.

Trace.—To carry out the great principle of so arranging the works of a fortress that the defenders may be able to use their weapons with the fullest effect against an enemy from the time he appears within range up to the moment of personal collision, it becomes necessary to make some provision (not hitherto mentioned) by which the exterior slope, faces of the escarp and counterscarp, and the bottom of the ditch, may be brought under fire.

This has been accomplished in two ways:—

1st. By breaking up the sides of the polygon (which may be supposed to surround the position intended to be fortified) into a series of bastioned fronts (fig. 8); or,

2nd. By throwing out at the salients or centres of the sides of the polygon low casemated works, called kaponiers or bastionettes (fig. 10), commonly called the "Polygonal Trace."

Bastioned Fronts.—To determine the length and position of the various lines composing a bastioned front, the following principles must be kept in view:—1st. The musketry fire from the flanks should be able to afford good defence to the whole of the ditch in front of the curtain. 2nd. The lines of defence should not exceed the length of the effective range of grape and case shot, viz. about 300 yards. 3rd. The flanks should form right or slightly obtuse angles with the lines of defence, and should be long enough to contain 5 or 6 guns, or as many as a besieger could place in counterbatteries on the crest of the glacis of the salient place-of-arms in front of the bastion. 4th. The angles which the lines of defence make with the exterior side and curtain should be as small as possible, in order that the salients of the bastions may not be unnecessarily contracted, their faces needlessly exposed to be enfiladed, and the flank defence to the curtain too obtuse. 5th. The bastions should be large and capacious; small bastions being very objectionable, as crowding men and guns

into a small space, and thus rendering them peculiarly exposed to the effects of vertical fire; also a breach occurring in a small bastion would be likely to open the whole of the interior, and thus prevent the garrison from showing a front larger than that of the storming party.

Supposing then that the relief of the flanks is fixed as $a\ b\ a'\ b'$ (fig. 9), and that the musketry fire, with the greatest admissible depression, reaches a plane passing about 4 feet above the bottom of the ditch in c and c', draw a line D O (fig. 8), along which to measure the curtain, and another line, D F, about 300 yards long, making with D O an angle whose tangent is $\frac{1}{3}$. Draw D E for the direction of one flank, making with D F an angle of 90° or 95°. Along D F set off D C = $d\,c$ (fig. 9); through C draw C B parallel to E D. If the flanks have both the same relief, D B will be half the curtain; if they have not, draw B C′ = $\frac{c'\,d'}{3}$, and making the angle C′ B O = C B D, through C′ draw C′ D′, inclined to the curtain similarly with C D, and therefore equal or very nearly equal to $c'\,d'$ in the profile. D D′ will be the length of the curtain so obtained, that it may receive a complete musketry defence from the parapets of the flanks. Draw the flank D′ E′ and the other line of defence D′ F′, similarly to D E and D F. This construction, if the relief of the flanks is at all considerable, will give longer flanks than desirable; if so, let the inclination of D F to the curtain be diminished, until the length of the flank is no more than requisite. If the angles of the polygon surrounding the position be those of a square or pentagon, the inclinations of the lines of defence to the curtain should not exceed angles whose tangents are $\frac{1}{4}$ and $\frac{2}{7}$ respectively; so that the salient angles of the bastions may not become too acute. It will also frequently happen that if the lines of defence are kept at the full length of 300 yards, the exterior side will become too long for the site required to be occupied by the bastioned front. The lines of defence will have therefore to be shortened; and if no alteration is made in the length of the curtain, the bastions will be diminished in size. Small bastions being, as was before remarked, highly objectionable, it will be generally more desirable to maintain their size unaltered and to diminish the length of the curtain; the undefended space hereby produced at its centre may be remedied by forming casemates in the flanks.*

These remarks will give a general idea of the mode that should be adopted in carrying out the principles above enunciated with regard to the form of Bastioned Fronts.

Counterscarp.—The counterscarp is usually traced in a circular form round the salients of the bastion, whence it is directed on the outer ends of the crests of the opposite flanks, so that every part of the ditch may be exposed to the fire of the flanks.

Polygonal Trace.—If the ditches of a work are to be defended by kaponiers, there is of course no need for breaking up the sides of the polygon, as is done in a bastioned trace, a fact which gives rise to many advantages, as will be explained in the remarks upon the German system.

If the kaponier is placed at the centre of the side of the polygon, the length of this side may be made as much as 600 yards, or may be diminished as much as circumstances of site may require, without at all interfering with the full defence of the ditch. If placed at the alternate salients of the polygon, the sides should then not exceed 300 yards in length.

The form of the kaponier varies of course considerably, but its general character is

* These casemates have of late years been very generally employed, not only for this purpose, but also for affording a low raking fire along the ditch in front of the faces of the bastions.

represented in fig. 10. It is a casemated work, containing usually two tiers of guns; five or six in each flank on the lower story, and as many on the upper story. The casemates in the salient parts are loopholed for musketry. It is very desirable that an open space should be left between the flank casemates to facilitate their ventilation.

Ravelin.—To impart additional strength to fronts of Fortification by affording a cross-fire upon the capitals of the polygons, by covering, in the bastioned trace, the shoulders of the bastion, and, in the polygonal trace, the kaponiers, and to give other advantages which will be enumerated in the remarks upon the different systems, ravelins (K L M, fig. 8) are generally added, consisting of an ordinary rampart, with a ditch in front, formed by two faces meeting in a salient angle, so directed that they may receive flank defence from the main work. A redoubt is frequently placed inside the ravelin to increase its defensive powers, and also to bring a reverse fire to bear upon the ditch, for which latter purpose some of its guns should be in casemates. The gorges of both ravelin and redoubt should be left open or closed only by palisades or thin walls, that no cover may be afforded by them to an enemy who has established himself in these works.

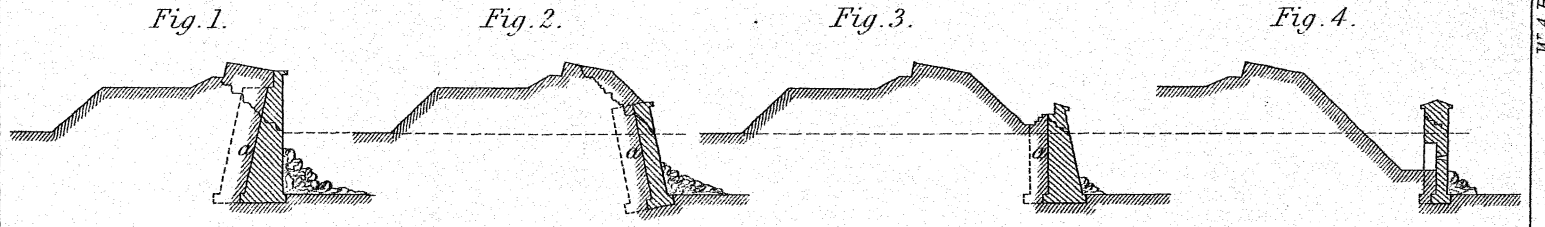
Covert-way.—The crest of the covert-way is traced parallel or nearly so to the counterscarp of the body of the place and ravelin (and at a distance of about 11 yards from it as before explained), except at their junction, where it is usually carried outwards in the form of a curve or salient angle, so as to provide large spaces for the assemblages of troops either for sorties or defence. These spaces are called re-entering places-of-arms (*a a*, fig. 8). The enlarged spaces left at the salients by the roundings of the counterscarp are called salient places-of-arms (*b b*, fig. 8). To protect the branches of the covert-way from ricochet fire, and to enclose the re-entering places-of-arms, traverses (*c c*, fig. 8) provided with banquettes for musketry are placed across the terrepleins, the interval left for communication between them and the crest of the covert-way being closed by barriers. Traverses should also be extensively used along the faces of any parts of works exposed to be enfiladed.

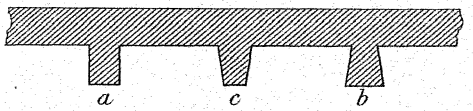
Tenaille.—The tenaille is a work (said to have been invented by Vauban) often placed in bastioned traces before the curtain. The lines of defence form its escarps. It must be separated from the curtain and flanks by an interval sufficient to secure its defenders from the splinters caused by shot striking the escarps. Its relief must be so regulated as not to impede the fire of the flanks. The great use of the tenaille is to cover the escarps of the curtain and flanks from being battered at so low a level as to permit of the formation of practicable breaches, but it causes undefended spaces in the ditch, and prevents the flanking of the main ditch in front of the faces of the bastions by means of casemates in the flanks.

Communications.—The communications, such as stairs, ramps, posterns, etc., should be secure and easy; for which purposes they should be placed as much as possible under shelter from the enemy's fire. They should also be well in view of the main work, in order that an enemy may be unable to make use of them without exposing himself to fire.

Bomb-proof Cover.—As was observed in the preliminary remarks upon the principles of Fortification, works of defence should afford cover to the defenders from *every* species of fire the enemy can bring to bear upon them, including of course vertical fire. As mortars are seldom carried by armies in the field, field-works need not in general be provided with the means of protection against this description of fire; but as they form an important element in all siege trains, it becomes highly necessary that all permanent works should contain sufficient bomb-proof cover for the accommodation of all the sick and wounded, and of such portions of the garrison as

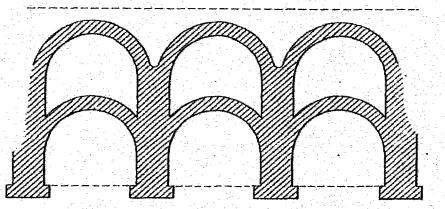
Permanent Fortification Pl.1.

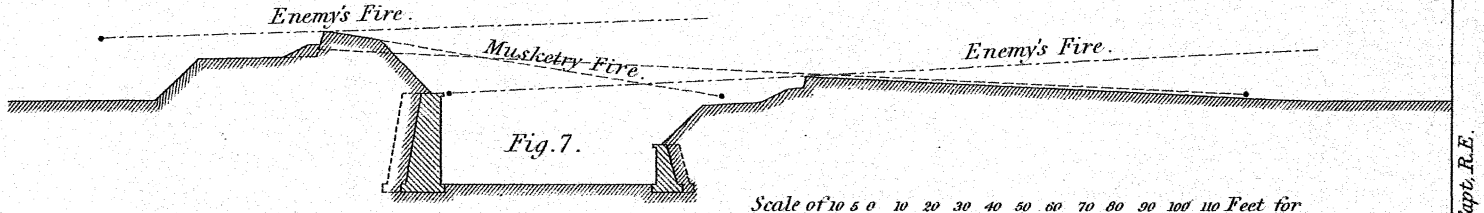




Scale of 10 5 0 10 20 30 40 50 Feet for Figs. 5 & 6.

$\frac{1}{360}$





Scale of 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Feet for Figs. 1,2,3,4,7.

$\frac{1}{720}$

W.A.Beever, Sc.

London, John Weale, 1857.

C.S.H.Capt. R.E.

Fig. 8.

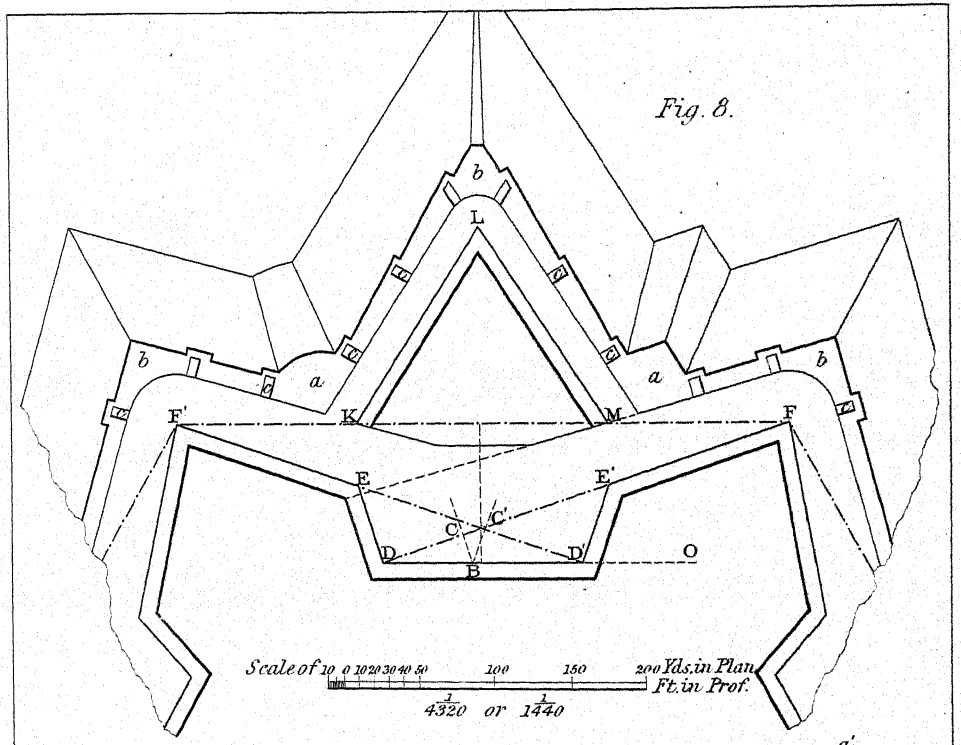


Fig. 9.

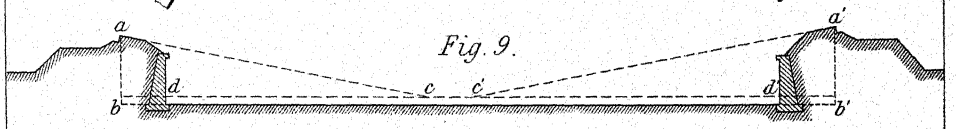
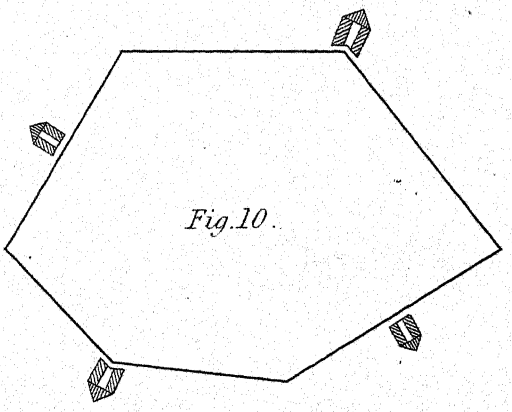


Fig. 10.



C. S. H. Capt, R.E. W. A. Beever. Sc.
London, John Weale, 1857.

are off duty. An ample supply of materials should also be in store for the erection of temporary blindages and splinter-proofs; the magazines of provision and ammunition should likewise be provided with bomb-proof cover.

SYSTEMS OF FORTIFICATION.

These remarks upon the general principles of Permanent Fortification being concluded, a description of the different methods of fortifying employed or recommended by some of the most eminent engineers will now be given, and their respective merits discussed, in the following order:—

1. Coehorn's System.
2. The French or Bastion System.
3. Montalembert's System.
4. Carnot's System.
5. The Prussian or German System.

COEHORN'S SYSTEM.*

SECTION I.—ADVANTAGES CLAIMED.

Coehorn was a Dutch Engineer who acquired a high reputation at the end of the seventeenth century, and proposed the three systems shown in the plate, which are especially adapted to ground but little above the surface of the water.

The first system has generally been considered the best, and it will be sufficient therefore to describe that.

The principal advantages which Coehorn proposed to obtain by the adoption of it are—

1st. *An increase of flanking fire* for the main ditch, by constructing two parapets in front of the main flank of the bastion, at different levels, so that a fire may be maintained from all simultaneously.

2nd. *Increased security against assault*, by building works inside the bastions and ravelins, revetted so as to act as keeps, and separated from the outer ramparts, which act as counterguards, by dry ditches, the level of which is only 6 inches above that of the water, so that it would be very difficult for a besieger to excavate trenches in them, and they would afford great advantages to the besieged for make sorties.

3rd. The power of *flanking the ditch* between the *inner and outer bastions*, by means of well-covered casemates constructed in large *orillons* placed at the shoulders of the latter, which also covers the lower flanks against enfilade fire, and affords additional fire from the parapets on its top to sweep the ditch and works in its *front*.

4th. *Security for the scarps of the bastions*, by the construction of narrow unrevetted counterguards in front of the outer bastions, which are also unrevetted, so that it is very difficult to make openings in the outer bastions through which to breach the inner ones; the terrepleins of the faces of the latter works are made very narrow, so that they may not afford room for a besieger's batteries, and loopholed galleries are formed along the rear, which facilitate mining operations, and afford a reverse fire into the dry ditches in rear; the communication with them is maintained by masonry *caponnières* extending across the ditches, which also afford a flanking defence to the latter; these, having their floors below the level of the water, are liable to be flooded if cracked by the blow of a shot or shell, and cannot therefore be relied upon, but this also allows of their being purposely filled with water if the besieger is likely to get possession of them.

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* By Lieutenant-Colonel P. J. Bainbrigge, R. E.

5th. *Redoubts enclosed by loopholed walls* are proposed to be constructed at the gorge of the inner ravelin, at the salient of the outer ravelin, and in the re-entering places-of-arms; and a wooden gallery is proposed to be formed in the glacis round each re-entering place-of-arms, having loopholes to afford a grazing fire of musketry over the surface in front; the ditch of the inner ravelin is also proposed to be flanked by a casemated caponnière extending across it near the main ditch.

The two faces of the orillon which are opposite to the ravelin and to the next orillon are built very solidly and counterarched, as a security against being breached. This work is connected with the shoulder of the inner bastion by a loopholed wall, having two gateways in it, opening into the dry ditch of the face; and between these gateways, and parallel to the face, is a line of palisades with gates to facilitate sorties.

The plan shows the trace of the curtain, which is broken, so as to lengthen the flanks, and also the trace of the tenaille, which, being indented, affords a low flanking fire to the main ditch.

SECTION II.—CAPABILITIES OF RESISTING AN ATTACK.

In order to judge of the capabilities of resistance of a fortress constructed according to this system, we must consider in what manner it would probably be attacked. If built upon the marshy site to which it is especially adapted, it would of course be difficult to establish the batteries required to silence its artillery fire; but as other systems may be applied to such a site, the advantages which the latter would afford should not be taken into consideration, and we must suppose that the site is such that batteries can be established in any position required, otherwise no fair comparison with other systems can be made.

As regards the first period of the defence, it will be remarked that there would be but a very small space available for placing *artillery* to resist the first batteries of the besieger, for the faces of the outer bastions and ravelins are not wide enough for that purpose, and there are only the faces of the inner bastions, each 50 yards long, and the salient of the inner ravelin available for this purpose; therefore the besieger would easily establish his first batteries, to delay the construction of which ought to be the great object of the besieged.

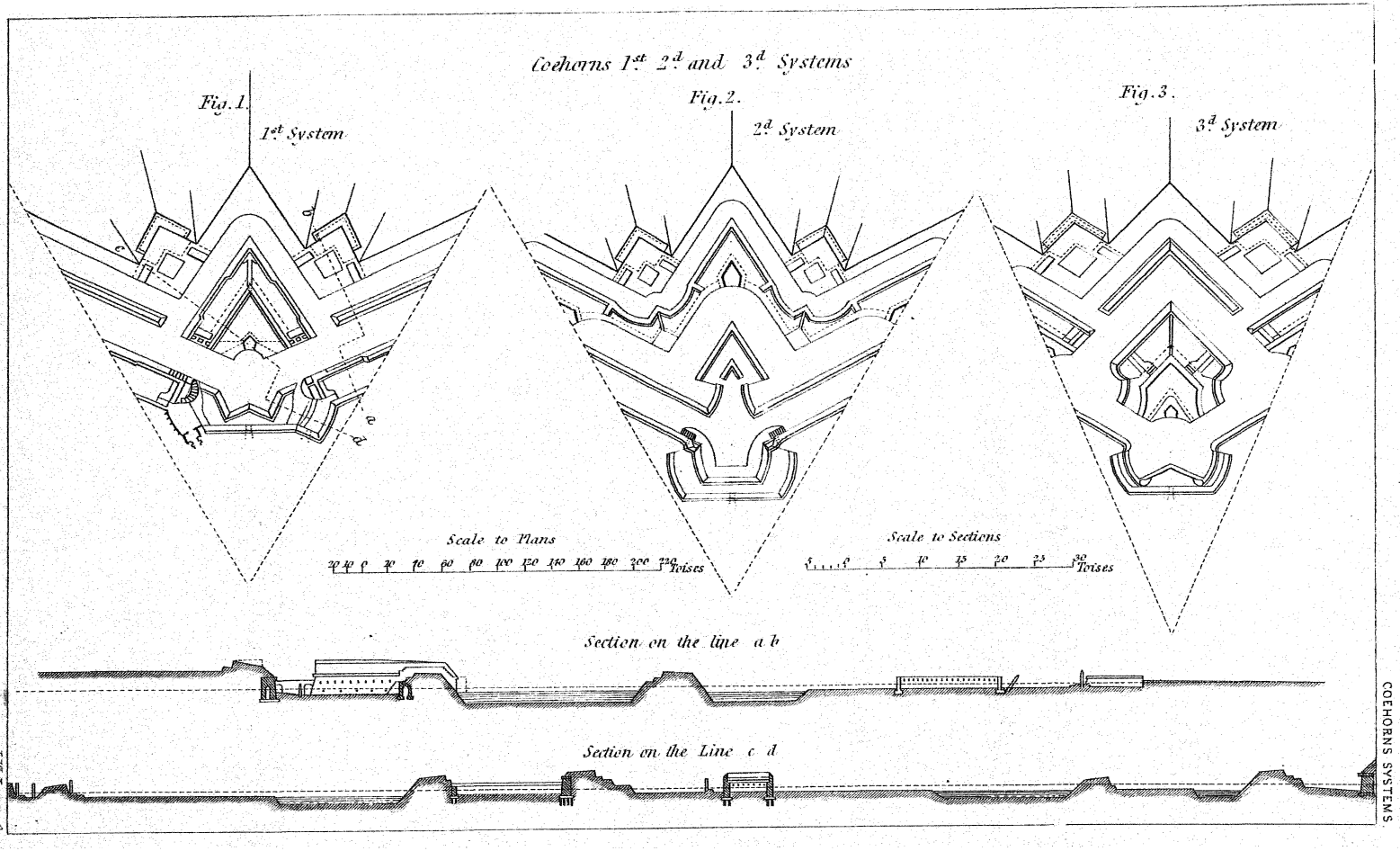
The faces of all the works are much exposed to be enfiladed, which would render the large space available for *musketry* of little use in checking the progress of the enemy's works in the second period of the siege.

Little advantage would be gained by the construction of the counterguards before the outer bastions, the latter being unrevetted, and this addition prevents the glacis in their front being so well flanked as it otherwise would be, therefore lodgments may be effected there more easily than in the glacis of a work constructed according to Vauban's first system.

The large wet ditches would prove great obstacles to further progress, and there would be great difficulty in constructing batteries to silence the fire of the triple flanks defending the main ditch; but the defenders of the two lower flanks would suffer great loss from the besiegers' shells caught by the works in their rear.

It would be very difficult for the besieger to establish batteries on the outer bastions to silence the casemates of the orillons, but after this is breached there is no flank defence for the face of the inner bastion, as the orillon masks the fire of the opposite bastion.

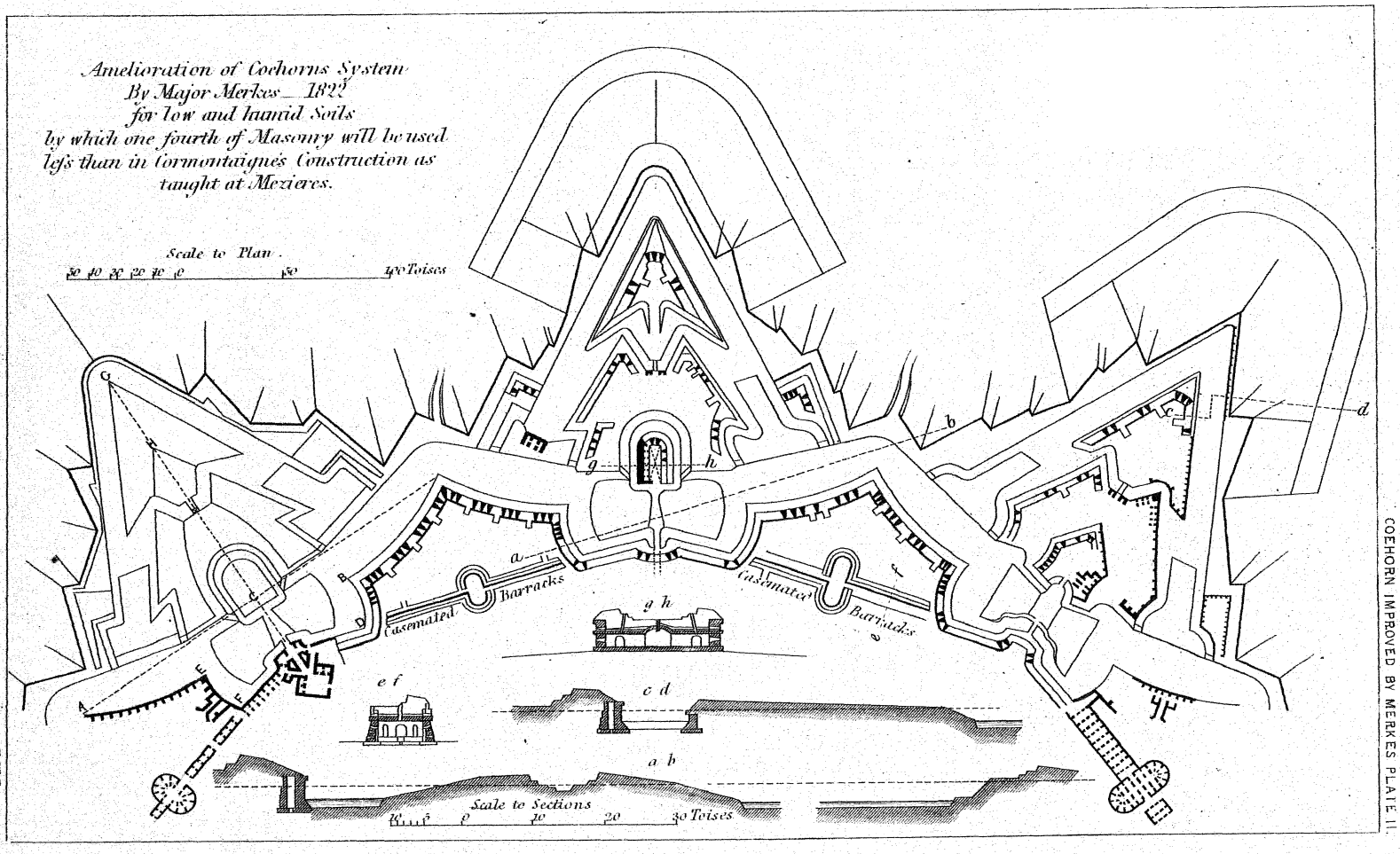
The outer bastion having a loopholed gallery along its rear, this would afford a reverse fire to defend the dry ditch, and would facilitate mining operations; but the access to it and to the orillon is very insecure, and all the works intended to be con-



John Weale 39 High Holborn 1847.

J. W. Lowry fc.

COEHORNS SYSTEMS.



John Weale 59 High Holborn 1847.

J.W. Lowry, C.

COEHORN IMPROVED BY MERKES PLATE II.

structed with masonry, except the orillon, are so slight as to be much exposed to destruction by vertical fire.

THE FRENCH, OR BASTION SYSTEM.*

SECTION I.

Vauban's trace, which differs but slightly from that of Pagan, (see Plate I. figs. 1, 2, 3, and 4,) may be considered as the basis on which the Bastion System is founded; the principal feature of which is the depth of relief, or command over the country (25 feet French).

Cormontaigne, profiting by the experience and the views of the illustrious Engineer who preceded him, made some essential changes in the construction of the Bastion System (see fig. 5 of Plate I.), more especially in the relief, and thus gave better cover to the body of the place. This, which is termed *fortification rasante*, and adopted by him, has become the distinctive character of the modern school.

Lieut.-Colonel Duvignau, who taught at the school of Metz until the year 1793, improved upon Cormontaigne, by extending the salients of his ravelins and giving casemated flanks to his redoubts. And the systems of Dobenheim, Lesage, and Col. Noizet, proposed several other changes as now taught (see fig. 6, Plate I.). In fulfilling the principles of Cormontaigne, they remedied the defect of the opening of the ditch of the ravelin, as likewise in the construction of the retrenchments in the bastions. About the year 1808, Bousmard and Chasseloup proposed their systems of placing the ravelins beyond the glacis; but the modern French school never adopted them, and preferred adhering to the principles of Cormontaigne, giving them all the improvements of which they are susceptible.

Among these is that of General Dufour, now Major-General of the Helvetian Confederation (see Plate II. fig. 1). This Engineer directs the faces of the ravelin according to the modern practice; and at the salient angle, extending 20 toises on each face, he places what may be called a cavalier (see fig. 2, Plate II.), which covers the ravelin by a break in the crest of the terreplein of 4 toises, and thus preserves them from ricochet, by the shelter which the cavalier on the salient angle affords them,—presenting to the enemy a dead mass of earth, on which it would be useless to expend his shot, and yet impracticable to establish a lodgment thereon, whilst it effectually covered the ravelin. The flanks of the redoubt of the ravelin have no terreplein, but consist of loopholed walls, with sally-ports sufficiently large for the passage of artillery; consequently the flanks are only adapted for musketry fire, for by this system the body of the place is not exposed. General Dufour proposes to close the ditch of the ravelin by a species of tenaillon, which he covers by a glacis, so that its escarp cannot be seen: this supersedes the necessity of a redoubt in the re-entering place-of-arms of the covert-way. It must be admitted that this construction obliges an enemy to crown the covert-way of the bastion attacked.

SECTION II.—OF THE SEVERAL MEANS TO ADD TO THE VALUE OF THE BASTION SYSTEM.

The fausse-braie, among the various means proposed, not only to correct the trace of the bastion, but to add to its defence, is the most defective, as it divides the body of the place into two stages, and facilitates escalades; and the lower level is untenable when the vertical fire of the besiegers commences, affording no command over the glacis. This description of fortification has been wholly abandoned in modern works.

* Taken from an "Essai sur la Fortification Moderne," par le Baron Emile Maurice, Capitaine du Génie. For details see page 42.

The fausse-braie must not be confounded with the *chemin des rondes* between the escarp and the parapet, which also was used in the old constructions, affording a good protection to the ditch and counterscarp by musketry fire. Vauban regretted bringing the chemin des rondes into disuse.*

Retrenchments in the Body of the Place.—That en cavalier (see Plate I. fig. 6) to be used when the bastions are large, and when a good command is desirable; but as they cramp the deployment of troops in the defence of the breaches, they should be constructed rather in the collateral bastions of the probable front of attack, and are thus judiciously placed in the forts at Lyons and Paris. The *retranchement tenaillé*, from the angle of the shoulder, is another resource for the defence of the breach, but also cramps too much the interior space of the bastion (see figs. 2 and 3, Plate III.).

The *retranchement bastionné* is preferable, particularly if it occupies the gorge, when it does not encroach on the bastion.

SECTION III.—ADVANCED AND DETACHED WORKS.

Hornworks—when established in front of a ravelin, expose the body of the place, (see fig. 1, Plate IV.); but placed before a bastion, this inconvenience does not arise (see fig. 2, Plate IV.), although it only removes the defect; for when the ravelin is taken, the angle of the shoulder of the bastion is exposed, instead of the salient. Besides, the hornwork, once taken, affords to an enemy, by the width of the terreplein, plenty of space to effect his lodgments. However, *hornworks* and *crownworks* serve to occupy ground in advance which accidental circumstances render inconvenient to leave to an enemy; but they are preferable when constructed beyond the glacis, of which there are good examples at Romainville, at Noisi and Rosny, at Paris, at Fort Vitriolerie at Lyons, and at Belle-Croix at Metz.

Lunette de Darçon.—The disadvantage of all advanced works has arisen from the difficulty of so constructing them as to render them independent: lunettes may have their faces and glacis flanked from the rear, but it is almost impossible to guard against a surprise† by the gorge. This defect General Darçon proposed to remedy (see Plate IV. figs. 3 and 4) by a circular tower, called a réduit de sûreté, not for the purpose of securing the garrison of the lunette, but to protect its retreat to the body of the place. The casemates secure the garrison also from vertical fire, and the ditches of the lunette are flanked by a reverse fire in the counterscarp. But the circular tower has no command over the country, and the summit is not constructed for artillery; and there is no covered communication with the body of the place. Plate V., figs. 1 and 2, represents a modification of the foregoing project, supplying, at the same time, improvements of which the lunette is susceptible. The first consists in the construction of the circular réduit, so that a good command is obtained, and the arches are sufficiently strong to carry heavy artillery; the floor below the summit is loopholed, to see the terreplein of the redoubt, and command the glacis of the gorge. The flanks and faces of the lunette are flanked by a reverse fire in the counterscarp.

SECTION IV.—BATTERIES CASEMATED A L'HAXO. TRACE OF CHASSELOUP.

Casemated Batteries à l'Haxo.—It does not appear that any trace can be found, even in Vauban or Cormontaigne, where the profile can be preserved for defensive purposes. The modern French Engineers have attempted to secure the fire of artillery without being so plunging as those en barbette, or so low as from casemated batteries in the flanks of the bastions, and yet have the advantage of being hidden

* See Jones's 'Sieges,' Note 25, vol. i. † *Ibid.*

to a certain extent from the enemy. And, instead of piercing the massive parapet with embrasures, a *casemated battery à l'Haxo*, the name of the inventor, is raised above the crest of the parapet on the terreplein (see Plates VI. and VII. figs. 1, 2, 3, and 4). The artillery, thus sheltered, has all the advantages of casemated batteries without the inconveniences attending them, such as the masonry being exposed, and the danger from splinters; as the embrasures are revetted with fascines, and the arrangement of the arches gives security from vertical fire, and a free circulation of air.

Chasseloup's Trace.—Le Général le Marquis de Chasseloup is the author of a system represented in Plate VIII. Without going into minute details, it will be sufficient to explain, that it embodies the following advantages:

1. That of keeping the enemy at a distance by means of outworks, well supported by the body of the place.
2. Of giving every facility to sorties.
3. Of obstructing the advance of the besiegers, by means of the casemated réduits in the advanced ravelin and covert-way.
4. Of securing the two covert-ways from ricochet.

The trace, of which Plate VIII. explains the project, has the exterior side ($x\ y$) 600 yards; but the faces of the bastion are broken, as shown at m and v. The flanks (n, o) have a line of defence equal to 400 yards, which is very great, considering that musketry is only effective at 200 yards. The small faces of the bastions (x, $m \times v$, y) are 70 yards; and the larger (m, n, v, n) are 170 yards. To construct the curtain, z, l is made equal to $\frac{1}{8}$ of x, y; and the flanks are constructed perpendicular to the line of defence; the salient of the ravelin is formed by extending it 250 yards from the front on line x, y; and the faces cover the bastions 100 yards from the angle of the shoulder. The salient of the caponnière (s) extends 100 yards beyond the line x, y, at s; and the faces are directed 50 yards from the angle of the shoulder.

The glacis (g, g) of the body of the place masks the latter from the openings of the ravelins, as well as the flanks of the caponnière; and it is impossible to enfilade the covert-way. And thus the besiegers must take the outworks or advance between the ravelins, and these being taken in reverse, the casemated réduit, as shown at l, s, sees into the ravelins, and the réduit of the ravelin gives still further security to the latter, which must be reduced before the body of the place is attacked.

This trace will be found to possess some resemblance to that of Bousmard, given in his Supplement to his 'Essai Général de Fortification;' but he made his bastions curvilinear. Chasseloup adopted the polygonal form, and his advanced covert-way has the disadvantage, like all other advanced covert-ways, of not being protected from the body of the place; and the opening to secure the retreat of the garrison when the ravelin is taken, is not so well contrived as Bousmard's; but the system of Chasseloup has been applied to the defence of Alessandria in Italy, under Napoleon: however, since the Peace of 1814, they have been destroyed. More detailed drawings may be found in Captain Macaulay's (R.E.) description of the works at Alessandria.

SECTION V.—CONCLUSION.

It is only now necessary to analyze the Bastion System, as to what characterizes the modern school, freed from routine and precise terms, making the study of the ground and the defilements the basis to work from, and which directs that the masonry of the works be well covered, that the outworks extend as far as possible, so as to oblige the enemy to capture them, or be liable to be taken in reverse as he

advances. And under the protection of these salients, the system admits of sorties and tactical operations.

It may be said that the casemated cover is too small and insufficient, whether in the flanks, or as reverse fire in the counterscarps, as likewise that the system does not admit of sufficient armament on the front of attack. It is true that only 70 pieces of artillery are provided for by the rules of the Service; but taking the system of Noizet, shown in Plate I. fig. 6, it will be found that it is possible to unite 160 guns and howitzers, and about 40 mortars, on the front of attack; as for example—

At the salients of bastion attacked	1
Twelve pieces to each face	24
Eight pieces to each flank	16
Five to each face of the cavalier	10
Twenty pieces to each collateral curtain, protected by blindages	40
One howitzer in each salient of ravelin attacked	2
Eleven pieces to each face of ravelin attacked	22
Two pieces in the re-entering place-of-arms	2
The two collateral bastions of the front of attack, five in each face	10
Four pieces to each flank of those bastions	8
Collateral ravelins, six for each face	12
Re-entering place-of-arms, with 6-inch howitzers, about	16
Mortars and pierriers in the curtains and bastions, about	40
	203

A certain number of these, to be covered by casemates à l'Haxo, which serve also as traverses, will be preserved infinitely better than those proposed by Montalembert.

The defect of the Bastion System, by exposing the body of the place through the ditch of the ravelin, is modified, as proposed by Noizet and Dufour (see Plate I. fig. 6, and Plate II. fig. 1), and the enfilade to which it is subject is removed by the projects of Dufour, Chasseloup, and Bousmard.

The improvements in gunnery by the introduction of Congreve's rockets, the perfection of Shrapnell's shells, and the invention of the Minié rifle, which will carry from 1000 to 1200 yards, and, finally, the 8 and 10-inch guns, which carry from 2000 to 3000 yards, and the Lancaster gun of still greater range, must all be considered, as they will have a considerable influence on the attack and defence of places.

SECTION VI.—DETAILS OF BASTIONED SYSTEMS.*—VAUBAN.

The terms employed with reference to the different parts of the Bastioned trace having been already explained (pp. 34–36), they will be used, as known, in the following details.

Vauban in his first system appears to have made his exterior side about 380 yards in length, with the faces of the bastions $\frac{2}{7}$ of the exterior side, and a perpendicular of $\frac{1}{8}$, $\frac{1}{7}$, or $\frac{1}{6}$ for a square, pentagon, or superior polygon respectively; the flanks being chords of an arc described from the shoulder of the opposite bastion as centre. The salient of the ravelin is found by cutting the perpendicular produced outwards by an arc described with the angle of the flank as centre, and the opposite shoulder as radius, the faces being directed to points on the faces of the bastions 11 yards from the shoulders. The counterscarp round the salient of the bastion is circular

* Partly from the papers used at the R. M. Academy.

at 38 yards' distance, and is directed on the outer end of the scarp of the defending flank, till it meets that of the ravelin which is parallel to the faces and round the salient of that work at 24 yards distant. The covert-way is 11 yards wide, the re-entering places-of-arms being found by measuring off a demi-gorge from 32 to 40 yards along the counterscarp, and making the angles between their faces and the branches of the covert-way 100 degrees. The tenaille has its gorge and end-walls 11 yards from the scarp of the place, its magistral line being formed by the lines of defence and its width being 17 yards throughout. Traverses are placed in the covert-way, one with its crest at the angle of the crest of re-entering place-of-arms, but perpendicular to the counterscarp, one with its exterior line in continuation of the magistral of the salient of the ravelin, and another halfway between these. Vauban's profile is generally treated as having a full revettment 40 feet high, total relief 43 feet, and thickness of parapet 18 feet. Bastions and curtains have a command over the country of 25 feet, over glacis of 17, and ravelin of 8 feet.

In Vauban's third system the construction at first is nearly the same, but instead of the curtain joining the ends of the flanks, an imaginary line in that position, produced both ways to meet the capitals of the bastions, gives the flanked angles of two pentagonal masonry tower-bastions, and a line is drawn parallel to this at 19 yards in rear of it; at 15 yards from the ends of this line, and perpendicular to it, flanks are drawn 11 yards outwards, and 8½ inwards. The above line is bisected by a perpendicular of 11 yards, through the ends of which are drawn lines of defence, the flanks being in the prolongation of those of the detached bastions.

The ditch in front of the tower-bastions is 15 yards wide, the counterscarp circular, and then directed on the outer end of the crest of the short flanks till it intersects the line joining the flanks of the detached bastions.

He also placed a redoubt in his ravelin, giving flanks to both.

THE MODERN.

In the Modern System, as commonly understood, the exterior side is about 384 yards, the perpendicular 64, and the faces of the bastions 128; the flanks are at right angles to the lines of defence, and have their magistral lines terminated by that of the curtain at their intersection with the production of the opposite face; the counterscarp of the main ditch being 32 yards wide round the salients, and directed on the interior crest of the shoulder. Generally, but not in all cases, a tenaille has been constructed 15 yards in width, with its gorge and end-walls 11 yards distant from the scarp of the work, and 6 yards of the crest at each end made perpendicular to a line from it to the middle of the entrance of the ditch of the ravelin. The ravelin has a salient angle of 60°, and its faces are directed on points on the faces of the bastions 36 yards from the shoulder; the ditch of the ravelin is 24 yards wide, and that of the redoubt in the ravelin 11 yards. The thickness of the ravelin is 17 yards, and the redoubt is formed with flanks 19 yards long, to fire on any breach which may be made in the faces of the bastions. The gorge of the ravelin is 2 yards in rear of the exterior side, and that of the redoubt is formed by joining the ends of its flanks at the intersection with the counterscarp. A ditch, 16 feet wide, with parapet in rear, called a coupure, is cut across and perpendicular to each face of the ravelin, the counterscarp being in continuation of the scarp of the redoubt in the covert-way. The covert-way is 11 yards wide, with redoubts in the re-entering places-of-arms, the capitals of which bisect the angle between the counterscarps of the ravelin and main ditch. A line, joining the salients of the bastion and ravelin, gives the counterscarp of one face of the redoubt; the other being on a line passing through the salient place-of-arms and the intersection of the first line with the capital, a

distance of 20 yards on which, beyond the counterscarp of the redoubt, gives the crest of the glacis, which is drawn in a circular arc, having the intersection of the counterscarps of the main and ravelin ditches for a centre. The scarp is parallel to and 16 feet from the counterscarp, and a length of 6 yards at the end of the crest next the ravelin is made perpendicular to a line drawn to it from the salient of that work, the crest of which is constructed with a face 9 yards long, perpendicular to its capital. The intersection of the above arc with the counterscarp on each side gives a point in the crest of the traverses enclosing the place of arms, which are 18 feet thick; the others, of which there are two on each face of the ravelin, besides those at the salient, being only 10 feet thick. In the ditch of the ravelin a traverse is formed, high enough to cover the scarp of the bastion from breaching, and having its superior slope running to the bottom of the ditch, with such inclination as to ensure its being swept by the musketry of the bastion. Its crest should be parallel to and 28 feet in front of the counterscarp of the main ditch. This traverse may be joined to the redoubt, but kept 12 feet from the ravelin to cut off communication; a banquette is formed, leaving a passage 8 feet wide with a retaining wall in rear, 6 feet in front of the counterscarp.

Communications.—A postern is formed through the centre of the curtain, at a slope of about 1 in 8, terminating 6 feet above bottom of escarp, a wooden ramp being added when required for use. A flight of steps leads on to the tenaille, under which a postern leads to an open caponnière, or double traverse, across the main ditch to within 10 feet of the gorge of the redoubt in the ravelin. Two flights of steps lead to the terreplein of the redoubt, under each flank of which posterns are formed, the communication across the ditch being protected by a single traverse. From this ditch a ramp, sloping 1 in 10, commencing at the counterscarp of coupure, rises to the terreplein of ravelin, a flight of steps leading to the part behind the coupure. Steps at each side of angle of gorge of re-entering places-of-arms lead to the redoubts, a postern below rampart of each face leads to the ditch, and two ramps in the counterscarp lead to the covered way, whence circular ramps conduct to the glacis for sorties, &c.

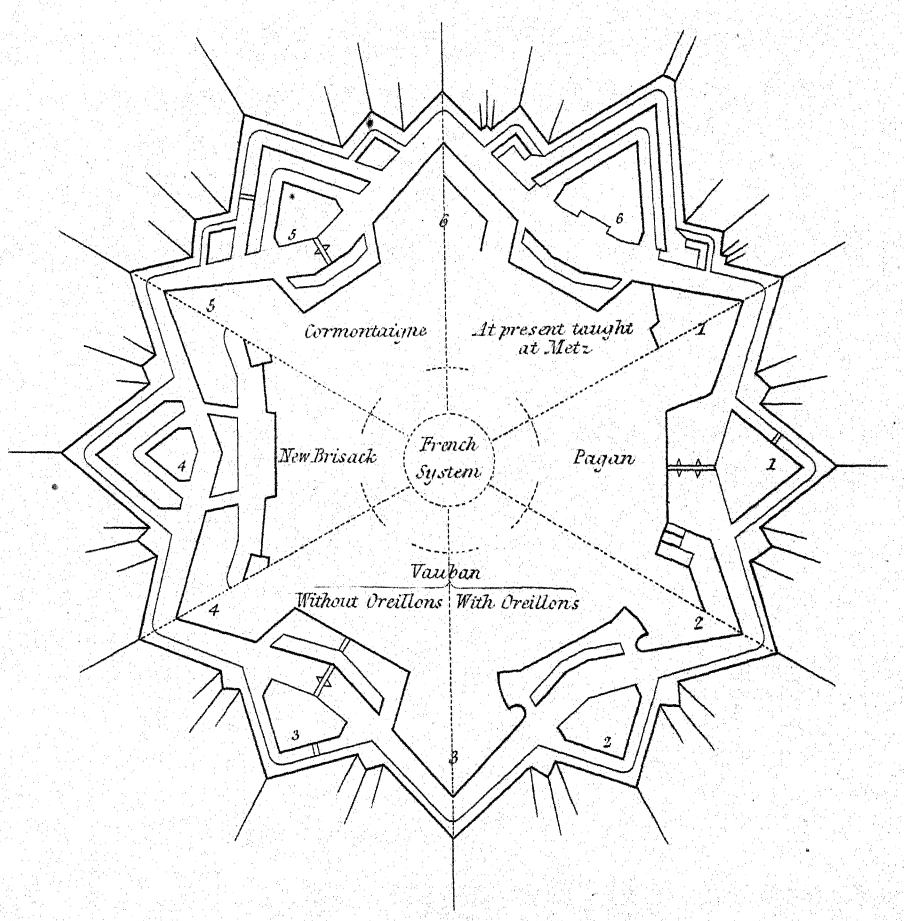
Reliefs.—Various reliefs are assigned, but about 44½ feet seems to be advantageous for the body of the place, giving a height of 14½ feet as command over the crest of glacis, and 23 over the counterscarp, allowing a scarp wall of 30 feet just covered by the glacis, and giving the glacis a slope of about 1 in 25. Relief of ravelin will be about 31½ feet, and its scarp 22 feet above its own ditch, which is 7 feet above the main ditch. Relief of the redoubt is 26½ feet, and its scarp 18 feet above its own ditch, which is 15 feet higher than the main ditch, by which arrangement it is defended throughout by the bastion. The redoubts in the covered-way have a relief of 24½ feet, and their scarps 18 feet above their own ditches, which are about 10 feet above the main ditch. The main work has thus a command of 3 feet above the redoubt in the ravelin; the redoubt, 3 feet above the ravelin; the ravelin, 4 feet above the redoubt of the covered-way; and that, 4½ above the glacis.

MONTALEMBERT'S SYSTEM.*

Mark René, Marquis de Montalembert, a French General, born in 1714, entered the service at eighteen, and assisted at the siege of Kehl in 1733; afterwards he was attached to the Swedish army during the Seven Years' War, where he saw the towers of the Swedish General Carlsberg, and from them he conceived the idea of his case-

* From Le Baron P. Emile Maurice.

Trace of the Principal French Systems used in the construction of Fortifications during the last 2½ centuries.



Scale of Toises

100 50 0 100 200 Toises

J.W.Lowry fc.

John Weale, 59. High Holborn, 1847.

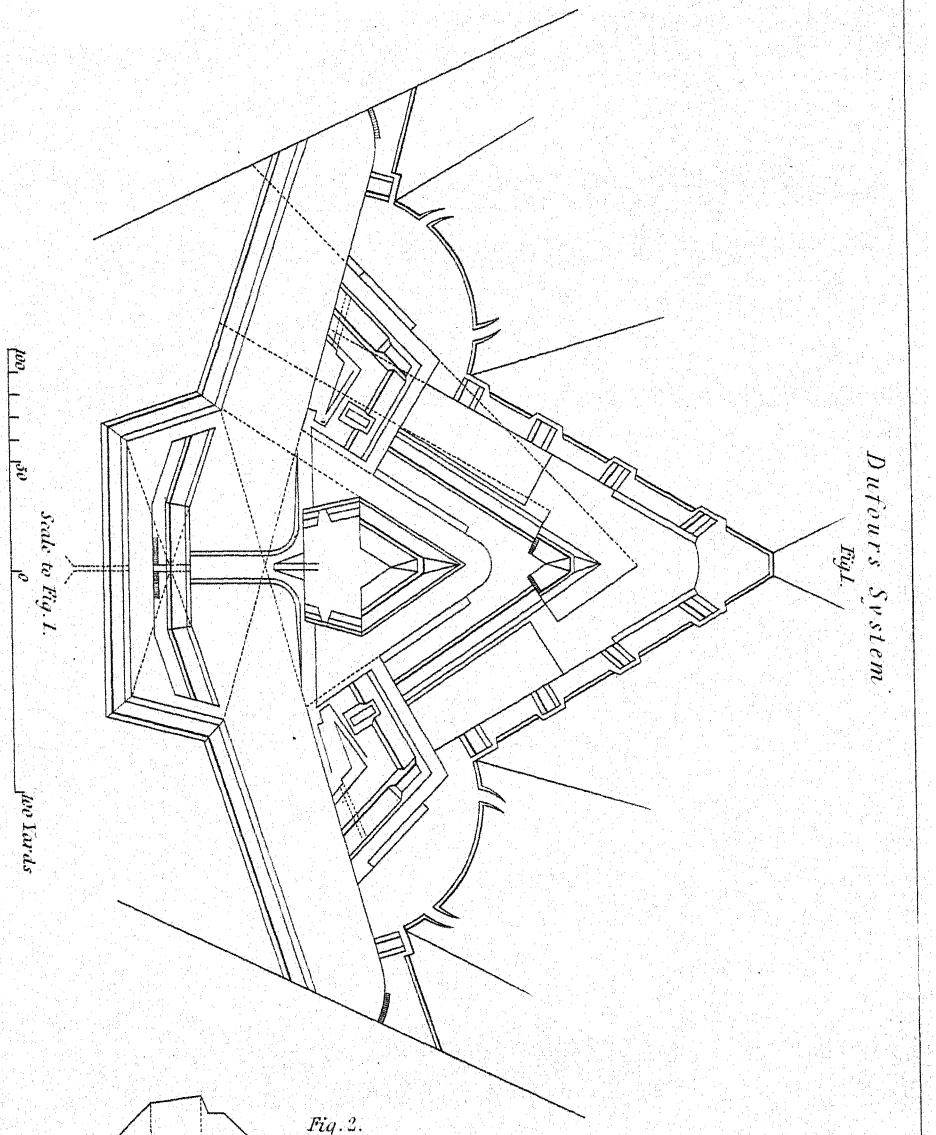
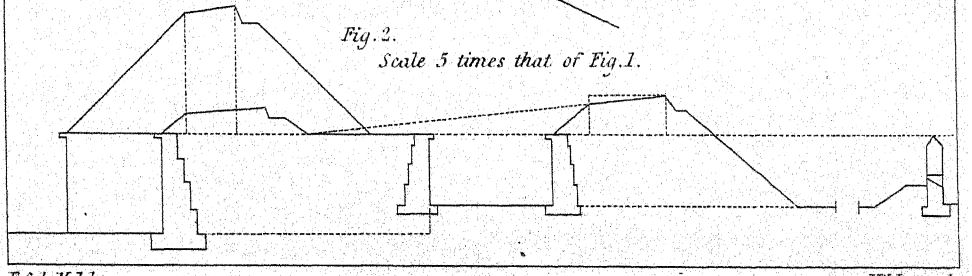


Fig. 2.
Scale 5 times that of Fig. 1.



E C de M.del. J.W.Lowry fc.

John Weale, 59, High Holborn, 1847.

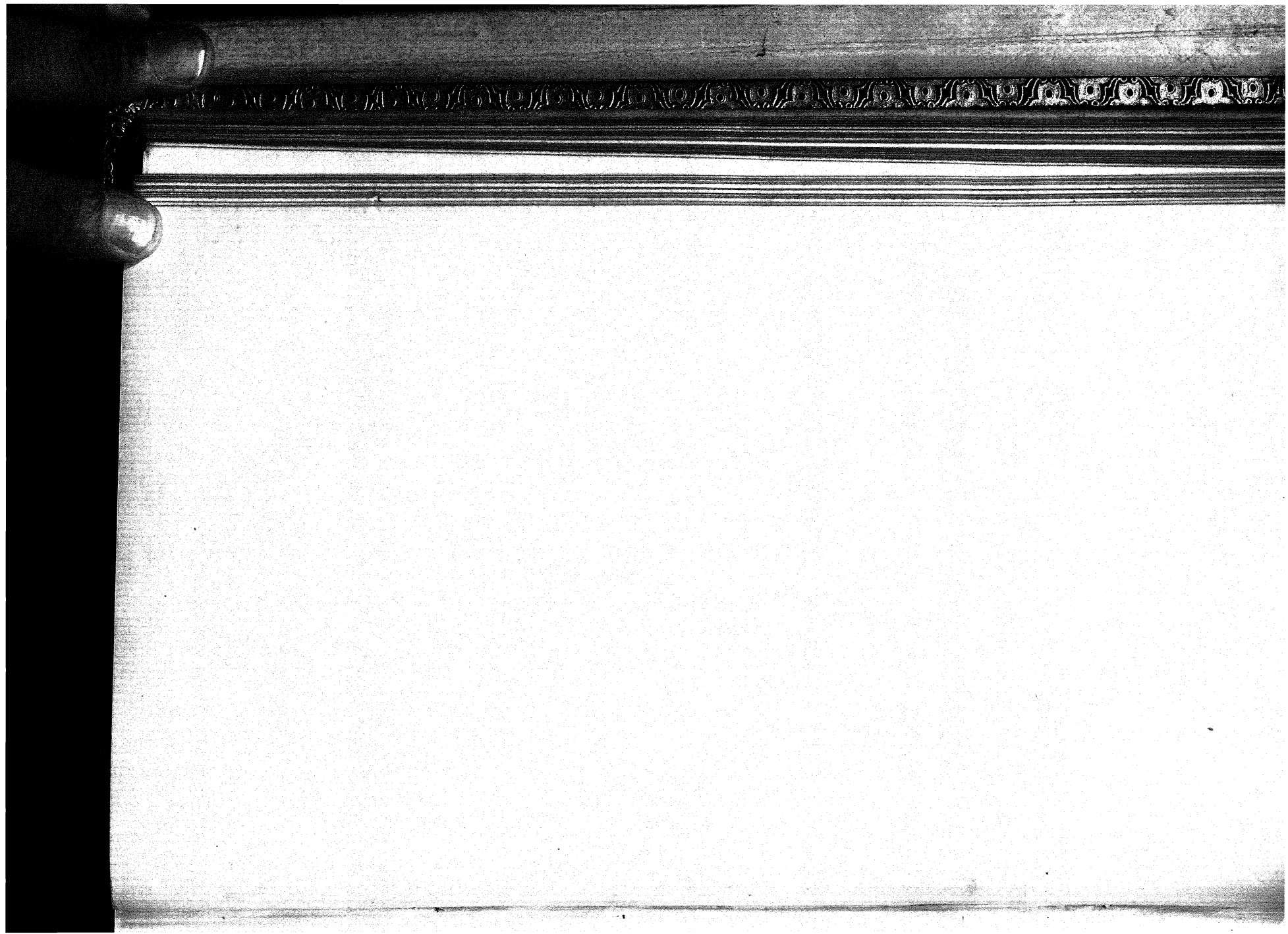


Fig. 1.

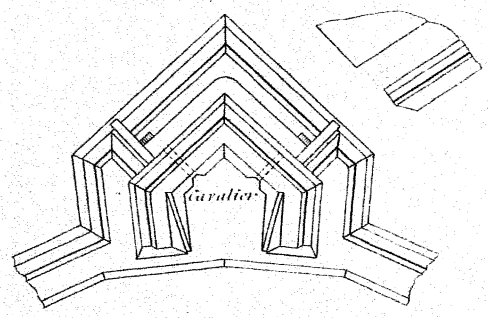


Fig. 2.

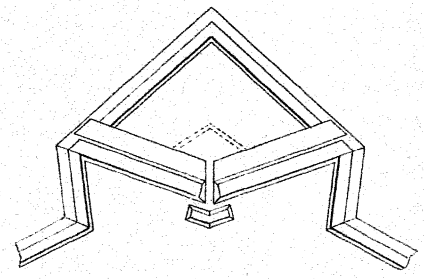
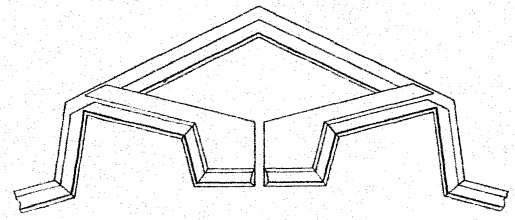


Fig. 3.



Entrenched Bastions.



Carnot, walls.

Fig. 4.

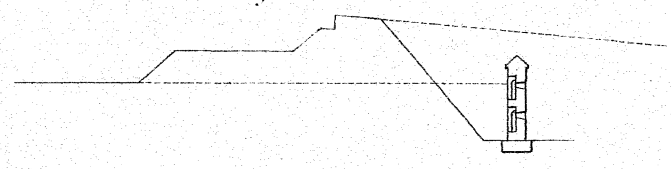
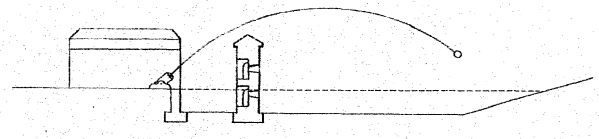


Fig. 5.



W. A. de Wint.

John Weale, 59 High Holborn, 1847.

J.W. Lowry, fc.

FRENCH OR BASTION SYSTEM, PLATE III.

Fig. 1.

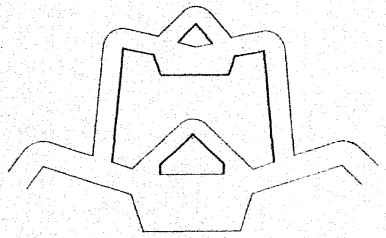


Fig. 2.

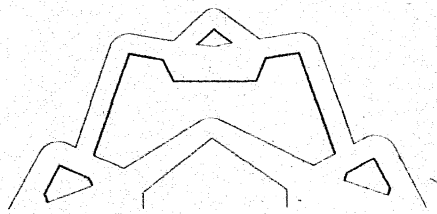
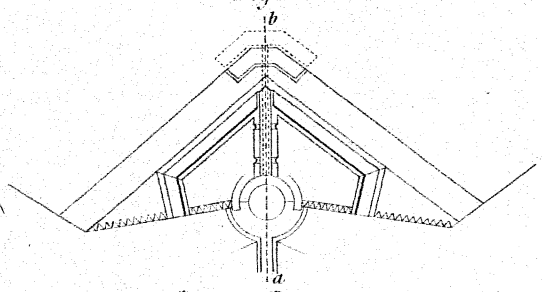


Fig. 3.



Lunette Dargon.

Scale to Figs. 1 2 & 3

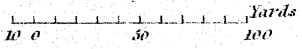
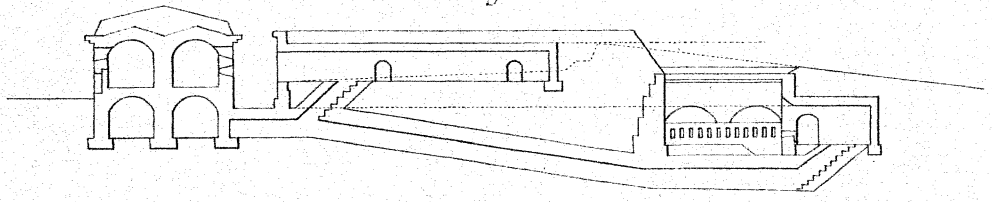
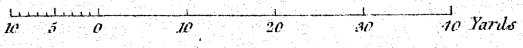


Fig. 4.



Section a b of fig. 3.

Scale to Fig. 4.



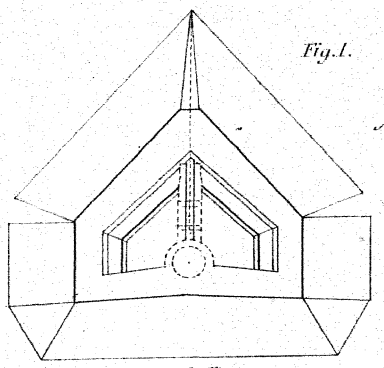
John Weale, 59, High Holborn, 1847.

J.W. Lowry, fc.

FRENCH OR BASTION SYSTEM. PLATE V.

Fig. 1.

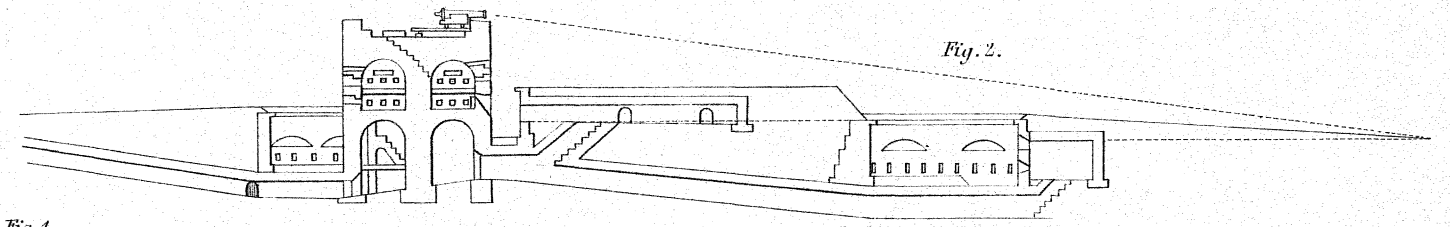
Advanced Lunette



Scale Fig. 1.

100 50 0 100 Yds.

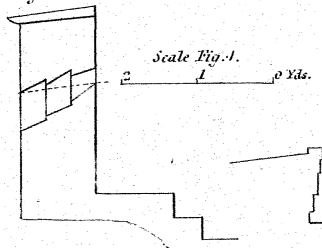
Fig. 2.



Scale Figs. 2 and 3.

10 5 0 10 20 30 40 Yds.

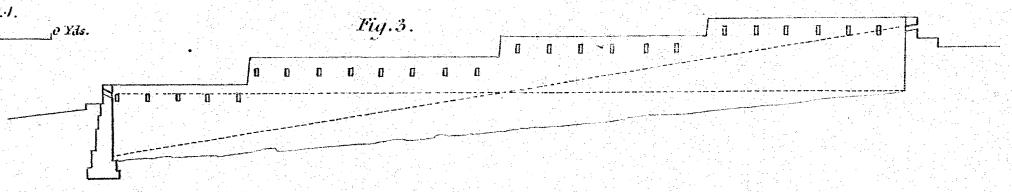
Fig. 4.



Scale Fig. 1.

2 1 0 Yds.

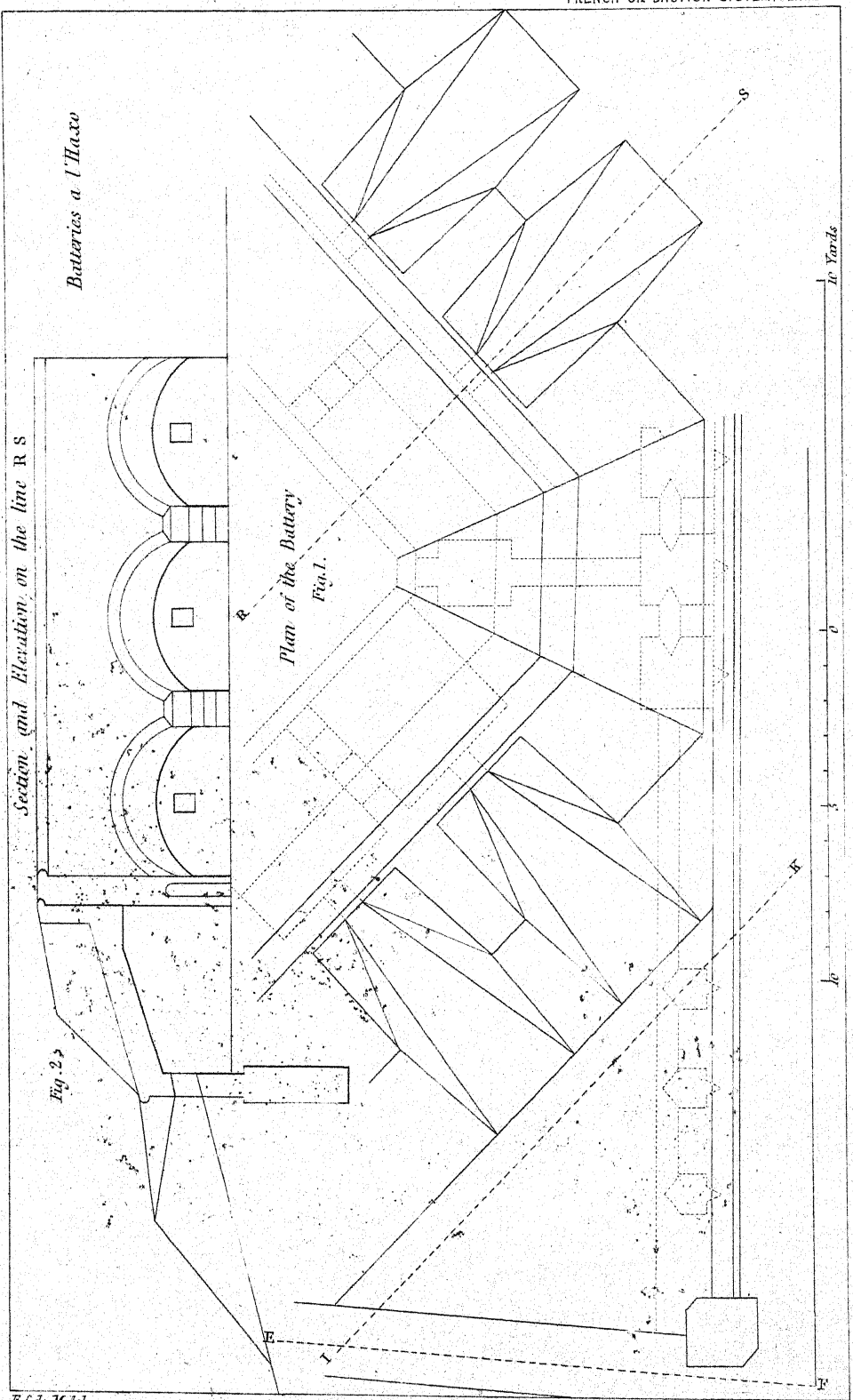
Fig. 3.



J.W. Lowry fc.

John Weale, 59, High Holborn. 1847.

A.C. del.



E.C de M. del.

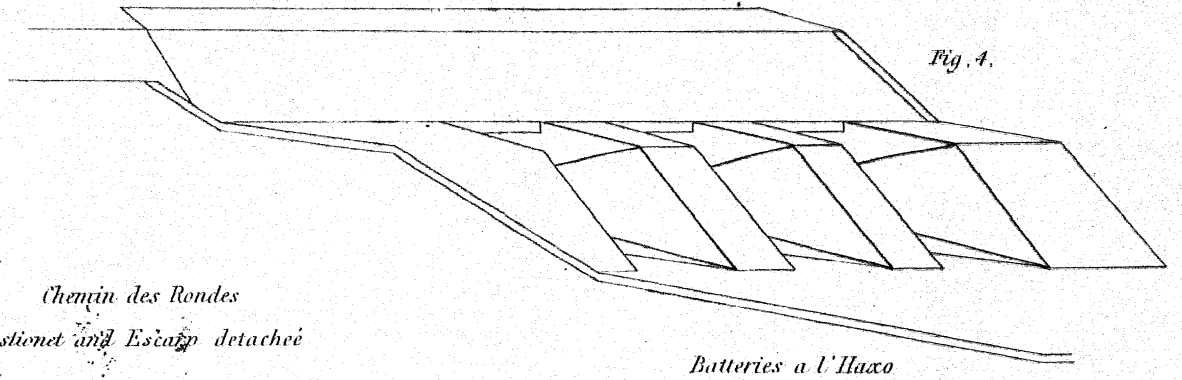
J.W. Lowry sc.

John Weale 59 High Holborn, 1847.

FRENCH OR BASTION SYSTEM. PLATE VII.

Elevation on the line E F *Plate VI*

Fig. 4.



Batteries a l'Haxo

Chemin des Rondes

Bastionet and Escarp detachée

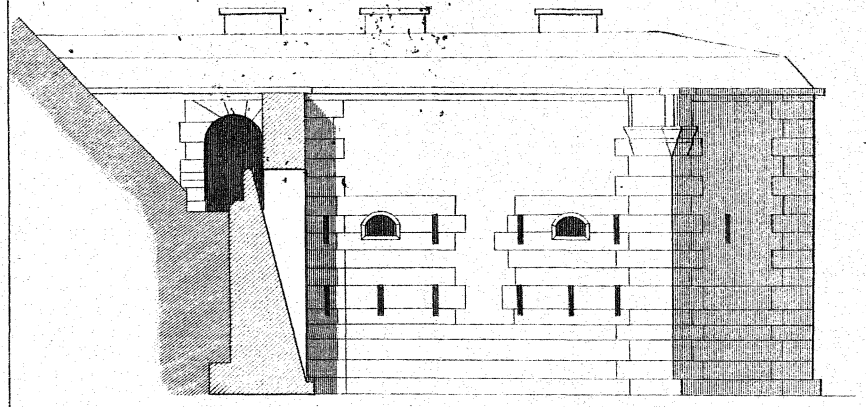
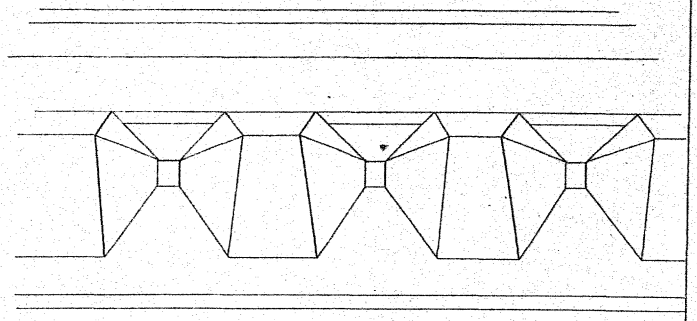


Fig. 3.

Elevation on the line I K *Plate VI*

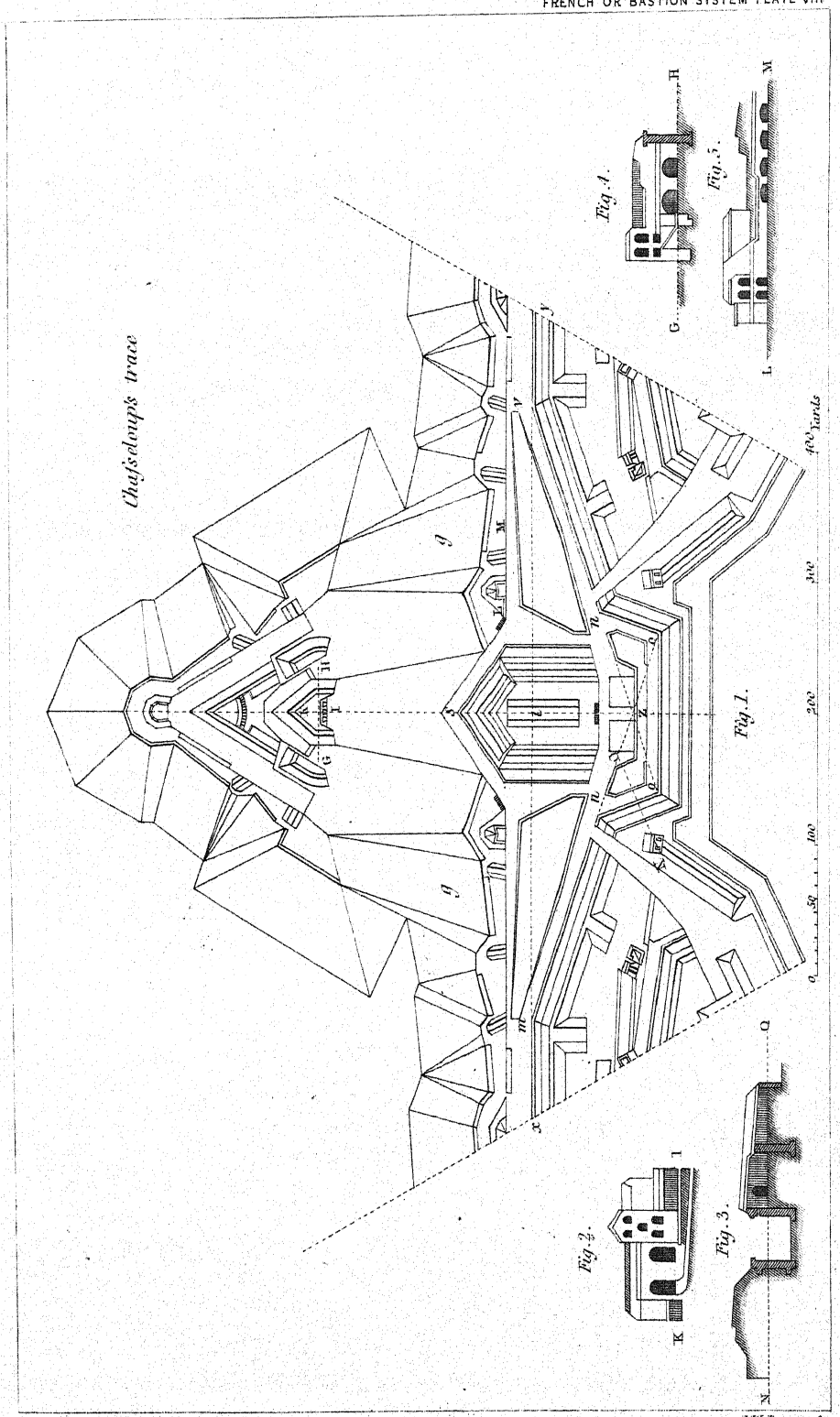


10 5 0 10 Yards

J.W. Lowry fe.

John Weale 59 High Holborn 1847.

E.C. de M. del.



J.C. del.

J.W. Lowry fc.

John Weale, 59 High Holborn, 1847.

mated towers. In 1776 he published his work on 'Perpendicular Fortification, or the Art of Defence rendered superior to the Attack of Places.'

The principles on which Montalembert based his system were violently attacked by the French Engineers, but Carnot adopted them, and the German System* has admitted their advantages, and followed them.

The trace (see Plate I. fig. 1) consists of converting the polygon into a series of re-entering angles en tenaille, flanked by casemated caponnières, instead of the Bastion system, with its lines of defence.

These caponnières (*c*, figs. 1, 3, 4, and 6, Plates I. and II.) are again flanked by casemated batteries of three stories, between the inner couvre-face (*s*) and the cavalier of the curtain (*m*).

The body of the place and the caponnières are surrounded by counterguards (*b*, *b*), and the re-entering angle of these flanked by casemates (*g*, *g*). In front of these, again, ravelins (*c*, *c*) with casemated flanks (*d*, *d*) are placed, and externally the whole has a covert-way and glacis.

Although the couvre-face (*s*) and counterguards have thin ramparts of earth, they have, near the foot of the exterior slope, a loopholed escarp of two or three stories, as shown in section, fig. 2.

Within the couvre-face (*s*), at each salient angle of the polygon, is placed an angular tower (Plates I. and II.), which has been much followed in the German System; and the fortress of Coblentz shows several of that construction. The tower is 40 feet in diameter, and four stories high, and its base forms a regular dodecagon, the salient angles having 60°, and the faces protect each other by a direct fire (see figs. 7 and 8, Plate II.). The external walls are from 3 to 4 feet 6 inches thick, diminishing from 18 inches to 2 feet. The second and third stories have embrasures lined with brick† for artillery; the parapet of the platform or upper story is also built of brick 10 feet thick, and the arch supporting it is 6 feet thick, of brick. The artillery to be placed on traversing platforms of his own invention.

Montalembert calculates upon the construction of traverses, when wanted, on these towers, to avoid ricochet.

Plate II. figs. 7 and 8.

In the centre of the tower he constructs a circular réduit, of which the walls, 6 feet thick, are loopholed for ultimate or final defence: the tower has likewise excellent magazines, well secured with hydraulic cement. It is alleged that the approaches are seen from the three stories of the caponnières (*c*), and those of the casemates and flanks (*g*, *g*), and of those noticed at *h*, and of the curtain (*k*), and of the casemated barracks (*n* and *w*), besides those from the couvre-faces and counterguards, and thus establish a fire from 430 pieces of artillery.

Nevertheless, works cannot see without being seen; hence the casemates (*d*, *d*) of the ravelin, those (*y*, *y*) and the loopholed escarps (*b*, *b* and *c*, *c*) would be immediately destroyed. Likewise the position of the caponnière (*c*), which is liable to be hit on each side, and would soon become untenable; when also the couvre-face (*s*), casemate (*v*), and defensible barrack (*w*), would be ruined by being open to the shot of the besiegers through the numerous embrasures. The military world must not therefore be imposed upon by the mass of masonry and double and treble tiers of embrasures of Montalembert's expensive system, all of which would be crumbled into ruins by heavy artillery at 800 yards' distance.

---

* M. A. de Zostrew, author of a work called 'Permanent Fortification,' observes, that a complete revolution has been worked in the art of fortification by Montalembert.

† Although shot, with a velocity of 1500 feet per second, will penetrate eight times its diameter in brick, yet in masonry works brick is the best material, in similar circumstances, to prevent splinters.

CARNOT'S SYSTEM.

SECTION I.

"Le nouveau mode de défense consiste donc dans ce jeu alternatif des sorties et des feux verticaux; de manière que l'ennemi ne puisse éluder ceux-ci sans s'exposer à celles-là, ni se mettre en mesure contre les premières, sans se faire accabler par les autres."

'*De la Défense des Places Forts,*' *par M. Carnot*, 3rd edition.

But what is the effect of this vertical fire, which has not been appreciated, and never made the basis of defence, as proposed in this system of fortification? (See Plate, Carnot's System.) It is to bring these means into play after the establishment of the third parallel, which it is supposed will be fixed about 50 toises from the salients of the ravelin; and as the usual bastion fronts are 180 toises, the space taken by the besiegers in advancing to the covert-way will be about 9000 square toises: but as it is probable that they may diverge a little to the right or to the left, the space may be considered 15,000 square toises.

Now this extent, it is fair to suppose, will be occupied by 3000 men, either employed in the siege operations, or as guards to the trenches, calculating the garrison at 4000 men: then, as each of the besiegers will cover one foot square, there will be 180 to every 5 toises square.

To oppose this force, let six 12-inch mortars be placed in each of the bastions and ravelin of the front attacked; that is, two on each capital, to fire on the zigzag approaches to the place; and as each mortar can throw 150 balls of 1lb., or 600 of ¼lb., the six can discharge 3600, which ought to destroy 20 men; and as 100 rounds can be fired per hour, 2000 men will be put *hors de combat* in 24 hours, or 20,000 in 10 days,—the probable period between the establishment of the third parallel and the opening of the breach.

Should, however, the besiegers attempt to secure themselves by blindages, the least sortie will throw them into confusion, without considering the immense quantity of timber necessary to protect themselves.

Hence the importance of vertical fire in the defence of places is demonstrated: 1st, by the impossibility, after the third parallel, to reserve any other fire; 2ndly, by the difficulty of reaching the besiegers in their trenches by any other means.

This description of defence, besides, is not reciprocal, and not available, as it has been before shown, to the besiegers, who have no cover, whilst the besieged are secure in their casemates, constructed on purpose.

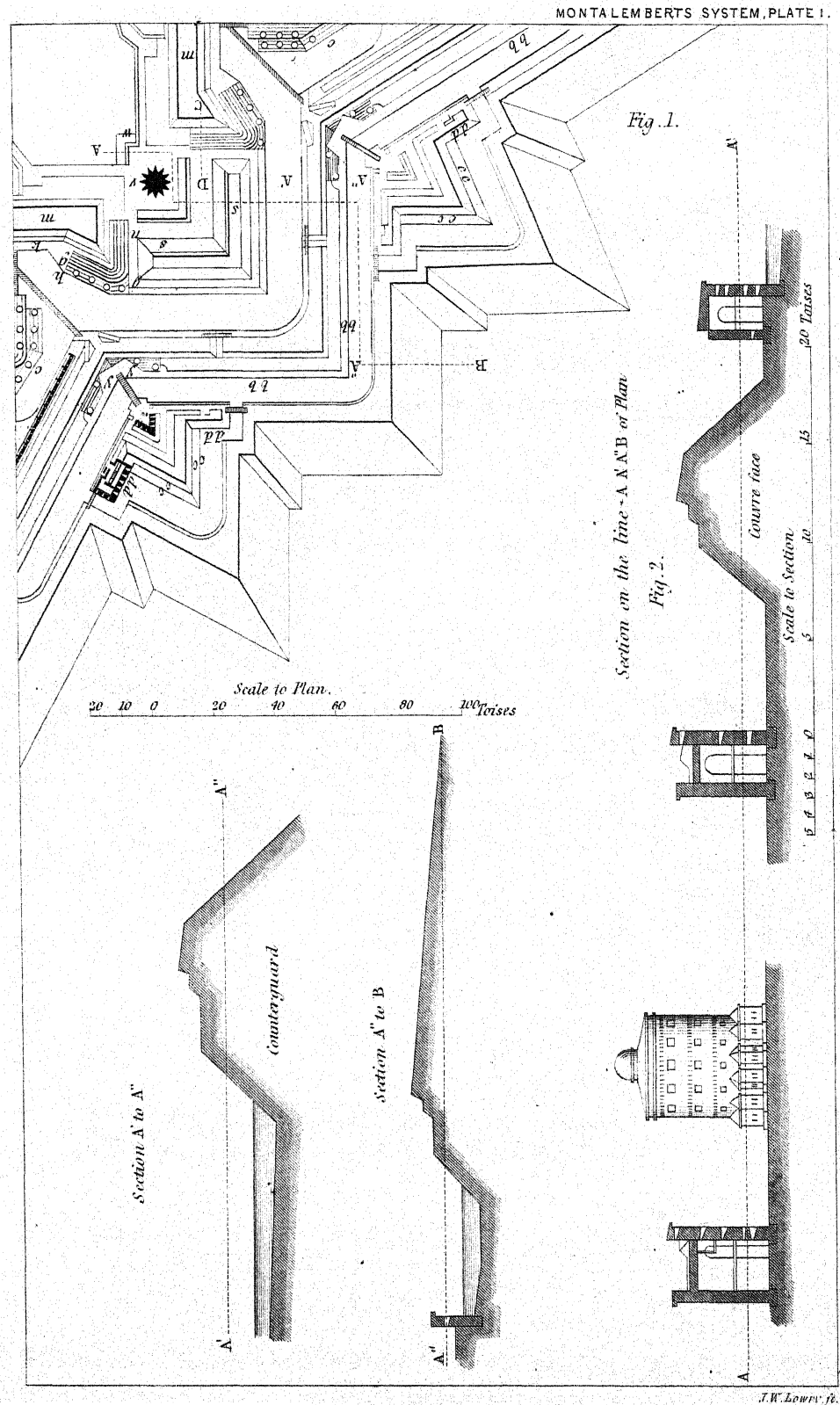
Plate III.—Figs. 4 and 5 of the Bastion System explain the manner in which it is proposed to organize vertical fire, in the existing systems, to be constructed in the capitals of the bastions and ravelins for 21 heavy mortars to each front, which arrangement does not interfere with the ordinary complement of artillery and musketry on the ramparts, which, when the besiegers obtain the ascendant, will be withdrawn, and the defence, as regards the artillery, will be left to the casemated batteries for vertical fire, for stones, grenades, or iron balls, according to the near approach to the covert-way.

SECTION II.—APPLICATION OF THIS PRINCIPLE TO A SPECIAL SYSTEM OF FORTIFICATION.

Plate, Carnot's System.

First, for Low Aquatic Ground (figs. 1 and 4).

As fortifications constructed on aquatic sites involve considerable expense, it is not possible but to admire the means adopted by Coehorn, with his limited resources, and the excellent principles inculcated by that celebrated Engineer.



John Weale, 59 High Holborn 1847.

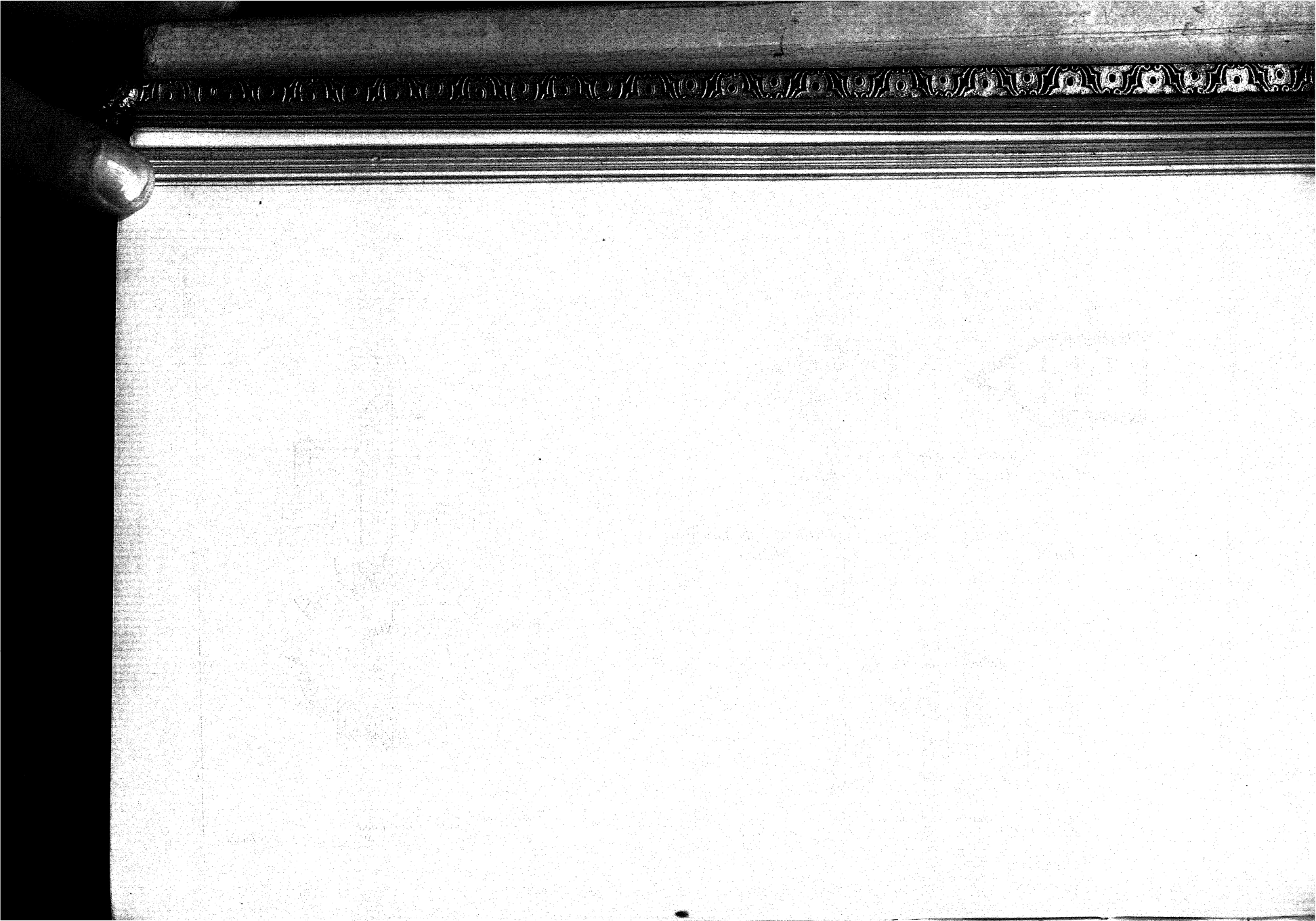


Fig. 3.

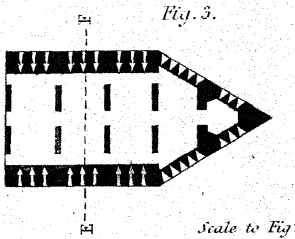
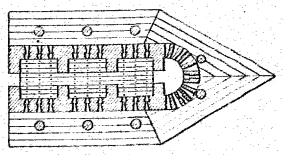


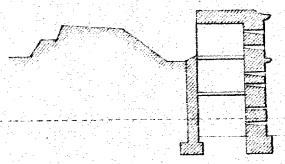
Fig. 4.



Scale to Figs. 3 and 4

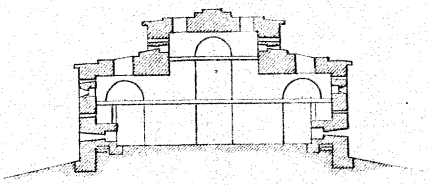
1 0 1 2 3 4 5 6 Toises

Fig. 5.



Section on the line C D
Plate 1

Fig. 6.
Section on the line E F



Scale to Figs. 5 and 6

5 4 3 2 1 0 5 10 15 Toises

Fig. 7.

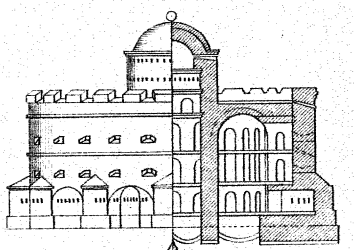
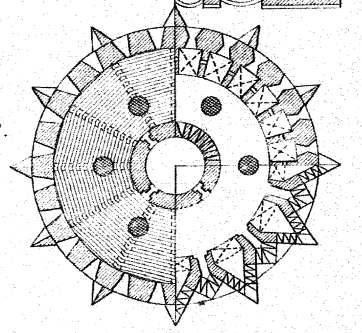


Fig. 8.



Scale to Figs. 7 and 8.

5 4 3 2 1 0 5 10 15 20 Toises

T. W. Lowry sc.

John Weale 59 High Holborn 1847.

Fig. 3. Section on the line A B for dry ditch

Fig. 4. Section on the line C D for wet ditch

J.W. Lowry fc.

John Weale, 59, High Holborn, 1847.

The great difficulty, in similar circumstances, is to find materials sufficient for the ramparts and glacis, and for that reason it is proposed to dispense with the latter; however, the security of the place requires that the enceinte should be complete and of the proper height against an assault. This enciente will be merely a loopholed wall of two stories, as shown in fig. 4, except at the re-entering angles, which will be casemated for artillery; and it will be perfectly hidden by the body of the place, on which it is necessary for the besiegers to establish their batteries to breach the wall. These (the loopholed wall and rampart in front) ought to suffice; but as it is necessary to communicate without by boats for offensive operations, a counterguard is placed parallel with the body of the place, also constructed of earth, shot-proof, yet so narrow that the besiegers have not space to lodge themselves on.

In proposing this system of defence, the bastion form is not adopted, as dead angles are of little importance with wet ditches; therefore the angular shape is preferred, on account of its simplicity and economy.

The details of this trace (see figs. 1 and 4) give an inner wall, as already explained, without any rampart, forming a series of redans, of which the salients (x, x) may be from 50 to 100 toises apart, according to the size of the polygon, the Plate representing a dodecagon. This wall, which surrounds the town, is built upon the natural soil to save expense, and is 6 feet thick and 24 feet in height, in arcades taken from the thickness of the wall (see fig. 4). At six toises in front of this wall is the interior slope of the body of the place; the latter is also 24 feet high and 18 toises wide, and leading from which are sally-ports to the tenaille, to cover the re-entering angle, and connect it with the place-of-arms on the counterscarp by an open earthen caponnière. The width of the counterguard is similar to the tenaille, 12 toises; the wet ditches are all 6 feet deep, and the glacis is contre-pente. The re-entering angles of the inner wall are casemated, with terreplein and parapet of earth, on which may be placed 16-pounder guns. These casemates are not an essential part of the system; but as bomb-proofs are necessary for a good defence, these serve the purpose.

Secondly, the application of the System to High Ground.

It has been observed that the bastion form is with difficulty adapted to uneven ground, on account of the length of the fronts, and that the angular trace is better suited to the inequalities of a hilly country: the same system is therefore preferred as proposed for that which is low and wet, with some modifications which local circumstances require.

1st. To give a greater height to the escarp, to avoid escalade; and 2ndly, to obtain a better command over the uneven ground without.

The details, as shown in figs. 2 and 3, give the inner walls 36 feet in height and 6 feet in thickness. The construction of the body of the place is similar to that with the wet ditches, except at the foot of the exterior slope, where a loopholed wall, 18 feet high, is constructed, as likewise all round the tenaille, to prevent surprise, to which the nature of the system with dry ditches, without a covert-way, is liable.

SECTION III.—REMARKS UPON CARNOT'S SYSTEMS.*

From the foregoing observations and from examination of the drawings, it will be observed that Carnot's systems are distinguished from those before described. First, by the suppressing of the counterscarp wall and the substitution for it of a counter-sloping glacis, so as to facilitate personal conflicts with the besieger (an arrangement

* From the papers in use at the R. M. Academy.

previously suggested by Rimpler); and second, by making vertical fire the basis of, rather than an accessory to, the defence.

With respect to the "Glacis en Contrepente," it can rarely happen that the garrison of any place is so strong as to have the means of making such formidable sorties as to require it along the whole of its exterior. By adopting it, the scarp wall must be more exposed, and an assault facilitated; a partial application of it might however be made in particular parts of a fortress, without sacrificing the whole of the covered way.

As regards the effects of vertical fire, it has been proved by experiment that Carnot has very much exaggerated them. It has been found that the number of balls that take effect is very considerably less than 1 in 180 (Carnot's assumption), and also that with projectiles of the proposed size (½lb. to 1lb.) the momentum of such as *do* take effect is not usually sufficient to place those they hit *hors de combat*.

ON THE MODERN SYSTEM OF PRUSSIAN OR GERMAN FORTIFICATION.

PRELIMINARY REMARKS BY THE TRANSLATOR.*

The new system of fortification, as being carried out throughout the whole extent of the German dominions, now claims our attention. (See Plates I. II. and III. figs. 1, 2, 3, 4, and 5, German System.)

The motives which led to the introduction of this new method may be briefly enumerated as follows, viz.:

The inefficiency of the various bastion systems employed, from Vauban and Cormontaigne, down to Bousmard and others, for a protracted defence, after the establishment of the third parallel.

The want of a free communication for troops within the works, for sorties, &c.

Also the inefficiency of the flanking fire of the various works under the old system.

Vauban, who was convinced by great experience that bastion fortifications, which he himself had built, were not able to oppose a sufficiently durable resistance to a regular attack, and that in the latter period of the siege they even accelerated the besiegers' progress in overwhelming the garrison, applied himself, in his latter days, to the object of strengthening his fortifications; and he endeavoured to accomplish this by means of *isolating his bastions*, connecting them by an entrenchment, and also by masked flanks.

Bousmard, in order to prevent or render more difficult the enfilading the faces and flanks of the bastions, gives them a flat curve, and also supplies the flanks of the tenaille with casemated sheds for the guns, to strengthen and secure the command of the main ditch.

These and other expedients have been proposed by various masters of the science; but have been found so complicated and expensive, that they have rarely, if ever, been resorted to in practice, however good they may have been in theory.

In the attack, as established by Vauban, of fortified places, the works are carried on (under ordinary circumstances) from the first, second, and third parallel, irresistibly, to the establishment of counter and breaching batteries,—the passage of the ditch,—the storming and consequent surrender of the fortress. Under the new Prussian or German system this will no longer be the case: the attack will be carried on as usual to the third parallel, or as far as the foot of the glacis;† but here will

* Colonel Stavely, late of the Royal Engineers.

† The attack up to this point will also be retarded in some degree by the difficulty of enfilading and by the mass of fire which can be brought to bear from the enceinte.—Ed.

commence a hand-to-hand and most destructive opposition, which will only cease with the capture of the last redoubt.

Before entering upon the details of the construction of the German System, we will take a cursory glance at its principal variations from the old and commonly received systems. First, then, we shall observe the increased length of the fronts or faces of polygons; these extend from 500 to 600 yards;—also the simplicity of the trace, which of itself diminishes expense.

Secondly, we shall remark the free communications for troops afforded by the works of the new system, as seen in Plates I. II. and III.

Thirdly, we shall notice the different system of flanking observed in it: this is usually done by means of *caponnières*, which, projecting from the centre of fronts of fortification, command the ditches in their full extent from the lower tier of guns, and the terreplein of the covert-way, with the crest of the glacis from the upper tier; with the incalculable advantage of their powers of defence being untouched and uninjured to the latest period of the siege, when all the best efforts of the garrison will be called into play.

Large and powerful *redoubts* are an invariable accompaniment of the new system in all its phases. These are of various construction, and depend much on the nature of the works. In small forts or advanced isolated works, they occupy the rear or gorge, not only as defensive barracks, commanding the interior or terreplein, but also as cavaliers, looking over the distant country and commanding the approaches: sometimes, as in the fronts of fortification surrounding a large town, they act as caponnières, and flank the faces, as in Plate III. fig. 5; in others, they are placed immediately in rear of the works as bomb-proof barracks, and also as cavaliers, thus affording secure shelter both from vertical and direct fire to the troops immediately on duty on the fronts attacked, and preserving them untouched and ready for the exertions required of them during the last periods of the siege.

By this brief exposition, it will be seen that the new system is not confined to any invariable rules, but adapts itself to ground and circumstances; and for this reason no single plan of a fortification will give a clear and adequate idea of the whole system.

We may also remark that there is a considerable difference between the *Prussian* and *Austrian* Systems, the former being employed generally in the North and West of Germany, and the latter in the Southern States.

It may be taken for granted, that the conventional dimensions of the details of works, as established by Vauban and Cormontaigne, are preserved; for as these authors only adopted them on the invariable rules observed in natural objects, and on the science of gunnery, as their basis,—they can only be changed by great improvements in the latter, as regards the range and calibre of cannon and musketry; and it is this, be it observed, which establishes in the new system the extent of the fronts,—the guns in the caponnières having on each side a point-blank range for grape and canister of 300 yards.

Thus far we have written, as forming preliminary observations to the present article, viz. 'A Description of the new German System of Fortification;' which object we think cannot be better effected than by giving here a translation of such portions of the work, published in Berlin, in March, 1844, by Major-General Brèze, Inspector of Fortifications, as are calculated to afford a clear general view of the subject, and without entering into minute details, which the limit of the article would not permit us to do. T. K. S.

"The spirit of modern tactics has been applied for some time to the Art of Forti-

fication, and the object has been to compose fortresses of single independent works, capable of affording a lasting resistance; but which are to be mutually connected, according to circumstances, by intermediate lines, thus forming a net of works expressly adapted for a step by step struggle for the possession of the ground; and which is to be carried on as long as the last part of the last work is tenable.

"If this object could be completely realized, then the ideal of a fortification would be obtained, and that again would lead to the ideal of a defence, such as the struggle at Saragossa from house to house, and from wall to wall, has shown to be practicable.

"When the fortifying of a piece of ground has been determined on by strategic principles, the Engineer chooses those points which, from their formation, must be considered as the most influential, and the best adapted to the consummation of the different military designs; also as the most necessary to be maintained.

"These points are made the main posts of the position. Casemated defensive barracks are constructed on them, in the form of *round towers*, or isolated *angular castella*, according as the range to be commanded from them may require the one or the other: they are built, according to circumstances, with two or three stories, and are furnished on the top with a gun-platform, sheltered by a parapet, which, in the manner of a cavalier, is to overlook and command the surrounding country.

"In this manner are obtained firm posts, which afford absolute safety against powerful enterprises, and oblige the enemy who is moving towards them to make a regular attack. The experience derived from Saragossa and Dantzig have already taught, on the one hand, how short and ineffective is the resistance of such works if their walls are quite exposed to a direct fire from heavy guns; on the other hand, what a lasting and effective defence they are capable of, if they are quite sheltered from the fire from without: it becomes necessary therefore, to shelter our towers and defensive barracks as much as possible from the effect of a direct fire, by means of lines of walls or ramparts thrown out in front.

"If the attack of artillery is practicable on all sides, then the towers must be sheltered all round; but if several of these works form together a position, having in its rear a large and independent main-work, then the construction of protecting lines becomes necessary only on those sides on which the enemy's advance with batteries and approaches is to be feared.

"That part of these works, then, which lies opposite to the main-work in its rear, may be considered as the gorge, and as such is only surrounded with a wall, to secure it against a coup-de-main, and to enable the main-work to be thrown open and sweep the interior of it, should the enemy succeed in establishing himself there. The defensive barracks or castella, protected from without, as high as the cordon of its walls, by the rampart thrown up in front, forms now the réduit of the whole work, and its height is so regulated that it may from its lower story sweep the terreplein of the work with musketry; and from its upper story, which is adapted for artillery, it may command the rampart, and attack, with a superior fire, the enemy's lodgement there, should he effect any; also, that it may fire over the rampart in front, on to the field of attack, from the gun-platforms lying over the casemates, which, in the manner of a cavalier, command the country.

"Besides, the covered story for guns is well adapted for placing howitzers to fire incessantly into the works of attack, approaching from the extreme edge of the ditch.

"The line of the rampart surrounding the réduit is placed as becomes necessary for sweeping the ground in front, and for flanking co-operation of the adjoining works.

"The escarp is generally revetted with masonry, and, in very exposed parts, constructed with a 'revêtement en décharge.'

"The ditch is flanked by masked batteries belonging to the work itself, which are constructed either in the independent *caponnières* of the ditch, or even under the counterscarp.

"The latter is supplied as a part of the system, and the covert-way, opposite the salient angle of the work, with blockhouses.

"This, in general, is the type of our independent works, as is also shown in Plate I. The perfecty safety of these works from being stormed is not to be doubted, and is secured in the last stage by the bomb-proof réduit, occupying the interior of them.

"The broad intervals between the single forts,—the spacious esplanades enclosed in them, and the far extending co-operation of the guns of the works, which protect offensive movements and cover retreats,—favour, in an extraordinary degree, the free movements of large or small bodies of troops in view of the enemy, either in advancing or retiring; also the enterprises of an effective garrison against a progressive regular attack will find energetic support and flank defence in a field of combat so well prepared.

"The step-by-step defence and possession of the ground may, by this method of fortifying, be rendered durable; which could never be the case by the older systems. Certainly the small extension of the lines of rampart does not enable the single works to oppose to the enemy's artillery an equal number of guns, which might be sufficiently numerous to enable them to engage in a short warfare, carried on by batteries; but this must be carefully avoided, in the defence of fortresses, unless you can rely on undoubted superiority; and then, by a careful application of the guns, you will succeed by keeping some ready, close under the 'bonnets' or traverses, to preserve them intact by means of woodwork and earth, in order to produce them at the right moment, when, by a few rapid discharges, they may bring the head of the sap to a stand-still, disturb the construction of a battery, or take advantage of any faults the enemy may commit; and though the use of the guns on the rampart be limited according to circumstances, yet the artillery will, by means of mortars and howitzers in its *numerous* and *covered positions*, be able to display an activity so much the more certain and uninterrupted, as its position is not materially endangered either by direct or vertical fire.

"In the next place it must be considered, that in the progress of a regular attack, in *each separate work*, every process incident to the siege of a fortress must be gone through; after which the assailants will be checked at each redoubt, which, of course, must be gradually overpowered by artillery, or by mines.

"This tedious and sanguinary operation must be repeated as often as there are single works which, by their co-operation, render their capture necessary.

"Let us, for example, take a fortification such as is represented in Plate I. (German System), and it will be seen here, that all four works, whose mutual strong flank defences and supports (as far as they are affected by firing from covered positions) cannot be destroyed by batteries in the parallels, must be taken one after the other; and the enemy cannot consider himself in possession of the ground, or of the avenue leading to the bridge, until he has taken the réduit of the fourth and last work.

"Now, if we compare this system of fortification with the older system of bastions, and consider the means of resistance, as well as the quantity of materials required for the construction and armament of each of them, we may obtain something like the following result.

"If the distance between each independent work be taken at from 700 to 800 paces, then a line of rampart (on the bastion system) which would surround and protect an equal extent of ground, would require a circumvallation of seven fronts of from

80 to 90 rods* in length. The expense of building this could not be taken under 1,800,000 rix-dollars, that is, giving it revetted escarps of the usual height—also ravelins and a covert-way over the counterscarp, and constructing the necessary buildings (only such as are commonly used) in the interior of the work, for keeping stores and provisions in.

"On the other hand, the cost of constructing the four independent works, whose covered defensive spaces afford at the same time bomb-proof shelter for troops, ammunition, stores, and provisions, would not, from experience, exceed 1,500,000 rix-dollars.

"The fortification on the bastion system, would, from its extent, require a garrison of at least 3000 men, with 120 to 130 guns and appurtenances, and provisions in proportion; whereas the whole four independent forts might be ably defended by 1500 men and from 80 to 90 pieces of cannon.

"The former would have to surrender, on a lodgment being accomplished on the glacis, and a breach made and stormed, *while the greater part of its works never took part in the struggle;* whereas the four independent forts cannot be considered as overcome, until the tedious operation of taking the works around each réduit is four times repeated; and then each réduit must be taken,—consequently, not until all means of defence have been entirely destroyed. Added to which, they can (with a much less expenditure of money and materials for their construction, armament, and defence) afford, when compared with the 'bastion enceinte,' a resistance three and four times as great, quite independent of the incalculable advantage they possess over the latter, in having bomb-proof places of shelter for the men and guns in those parts where they are wanted,—thereby causing a great saving, and obtaining a longer use of the forces and materials used in the defence,—affording rest for that portion of the troops which is not actually engaged, but kept near at hand as a reserve,—and lastly, in the confidence gained by the garrison, from the knowledge of the great strength of their works. All these advantages cannot fail in producing a good moral effect on the troops: besides, in an independent work of this description, a daily relief of the garrison is not required; but its defence would be permanently entrusted to one division, which would take up its quarters in it, arrange the different garrison duties, and learn to consider the work as its home, the defence of which would be a point of honour, and the men would join their own existence to the last heap of ruins.

"The other works, not immediately attacked, are required to render every assistance to the post that is engaged, by means of their guns, and also by offensive movements, checking the progress of the works of attack by frequent sorties; thereby keeping up the communication with the garrison that is attacked, in order to supply its various requirements.

"No work must be abandoned until all means of defence have been exhausted. Now, if the tenour of the foregoing remarks be summed up, we shall obtain the following maxims, which are observed by us (*i. e.* the Prussians) in the organization of our new fortresses, consisting of *isolated works.*

"Each independent work opposed to a regular attack receives covered as well as open gun-platforms, for the different kinds of ordnance, in their appropriate positions. The ditches are flanked by covered spaces, in order that the men who are constantly on duty here may be sheltered from a coup-de-main, hand-grenades, and the weather. This flank defence of the ditch, corresponding to the isolation of the work, is connected with it, and also with the redoubt, if possible, by means of covered commu-

* A rod is equal to 12 feet 4½ inches.

nications; but it is not entrusted to an adjacent work that is separated from it. The masonry, as well as the covered batteries, must not be exposed to direct fire from the parallels.

"Each work must have a bomb-proof place of resort for those men who are off duty. This place, and the magazine for several-days' provisions, are both connected with the principal redoubt, lying in the interior of the work, and sheltered from the fire from without.

"This redoubt (if peculiar circumstances do not prevent it) is pushed into the gorge of the work, to gain thereby a more spacious court in front of it; to obtain a sufficiently safe position for the gorge and gateways; to enable the works lying behind the redoubt to observe its condition when engaged in close combat, and render assistance accordingly; and, finally, to allow those of its covered guns which project from the branches of the redoubt, out of the wall of the gorge, to take in reverse or flank from behind the defences of the gorge, the enemy's lodgments on the glacis of the adjoining works. This is shown in Plate I.

"By means of this co-operation of the redoubts, the relative strength of the independent works, standing with mutual reference to one another, is greatly increased, and their possession, which is only to be accomplished by a great sacrifice of time and forces on the part of the besiegers, is made a necessity to them.

"The covert-way, with its blockhouses and undermined glacis, forms a first strong line, which can only be taken possession of by means of *sapping and mining*.

"The rampart, with its covered flank defences of the ditch, forms a second and stronger position behind the first; and to pass which, counter and breaching batteries must be erected.

"The redoubt, in the interior of the work, as a 'centre and commanding cavalier,' forms, lastly, the strongest part of the whole, and is generally only to be overcome by mining, provided the nature of the ground be adapted for it.

"By reference to the foregoing statement, we shall come to the conclusion, that thus one of the main objects of the art of fortification is accomplished; viz., that the strength of each part of the whole of this system, rampart, réduit, or caponnière, whether acting as flank or front, is, during the progress of the siege, fully developed, so that no one of them acts only a passing or ineffectual part, or falls at its close unscathed into the hands of the enemy.

"The Fort of Kaiser Franz, at Coblentz, situated between the right bank of the Moselle and left bank of the Rhine, has been built with the same views that dictated the formation of a fortification composed of single independent works, as represented in fig. 2, Plate II. This fort commands the passage over the massive bridge of the Moselle; it has the Moselle front of the town as a basis behind it, and the west or Rhine front of Ehrenbreitstein on its right; both fronts command the interior of this large tête-de-pont, which, from its construction, is, simple as it may appear, in a high degree capable of defence, and, from its means of affording cover, is as comprehensive as it is conducive to the movement of troops; above all, the independence of the principal part of the fortification, the systems of réduit and retrenchment, *first used in the new works at Coblentz*, stand out prominently and distinctly, and have since been used by us (the Prussians) as well in the large new fortifications of Cologne, Posen, and Thorn, as also in enclosing and strengthening other fortified places, such as Saar-Louis, Jülich, Wesel, Minden, Erfurt, Spandau, Kustrin, Glogau, and others.

"In other States also, the system of independent works is becoming the prevailing one; as, for instance, in the new outworks of Mayence,—the tête-de-pont at Ingolstadt,—at Gemersheim,—in the towers of the entrenched camp of Linz, and in many

other newly-projected fortifications.* With regard to the latter, the general principle seems to be, that a massive tower or bomb-proof redoubt of a different form should be sheltered from a direct fire from without by means of an earthen-work thrown up in front; but this cover, on both sides, is only to extend back so far as to enable the redoubt behind its wings to give a strong flank defence to the adjoining work. *Vide* fig. 3 in the Plate II.

"*Great towns* lie mostly on rivers,—those arteries and defensive lines of the interior of the country, on which its strategic defence mainly depends. They are generally built where the principal great roads cross a river; they form the conflux of the traffic and prosperity of the province; they contain the money and the means wherewith to carry on the war; and it is therefore as indispensable to preserve these treasures for one's own use, as to keep them from the hands of the enemy.

"Owing to this, the fortification of large towns has always been a main object with *us;* and with reference to the past and present, we have only to look at Magdeburg, Erfurt, Stettin, Dantzig, Cologne, Coblentz, Posen, and Königsberg.

"The fortification of such large places however presents generally many difficulties, not only on account of the formation the ground may have near the bank of the river, but also on account of the considerable expense incurred by the great extent of the enceintes; and it has therefore often been inquired, whether it would not be advisable (from the various advantages presented by the application of isolated independent works, both with regard to their capability of offering a long resistance, and also of favouring, in a high degree, all movements of troops,) to abandon entirely, in the new fortifications, the connected circumvallation of large places-of-arms and towns, and place in their stead only a chain of strong detached works, but which should be near enough to one another to prevent, by their mutual co-operation and cross fire, the enemy's endeavours to push in between them.

"This may do in theory; but practice will decidedly condemn it.

"The Maximilian towers at Linz are only expressly intended for forming an entrenched camp, which is to give an army, in case of its being defeated on the Upper Danube, a safe position on both sides of the river, and then to enable it, according to circumstances, to act again on the offensive, should the enemy advance; also to assist the line of operations.

"Linz can therefore in nowise be considered as a fortress, though *unforeseen circumstances might* require that the town, with its surrounding towers, should for a time be entrusted with a garrison of several thousand men, to prevent so important a place from falling into the hands of the enemy without a further struggle. According to report, it is intended, in the event of such a case, to close the intermediate ground between the towers with field fortifications and palisades, and to subject their re-entering lines to the flank defence of the towers. But will the garrison ever be strong enough to complete this enclosing operation in right time, and to a sufficient degree? May not then the reproach be justly made, that during a peace, when there was no want of time and means, they let slip such a fair opportunity of giving the whole position a solid basis by a fortification of this description?

"And will these works, constructed in a hurry, be ever sufficiently strong to secure the town and its magazines from being suddenly broken into at night by a force perhaps ten times as great as that of the garrison?

"Even for a strong garrison, the task of defending for a long time a fortification consisting only of isolated works is always a difficult one: the attack always commands a force sufficient to ensure reliefs and rest; in the defence they must be constantly on the *qui vive.*

* Austrian.

For these and other reasons it therefore appears *imperative* to enclose the principal inner parts of a fortification (the centre of the whole) with a connected circumvallation, which is besides indispensable on account of the shelter required from a direct fire from without.

"Accordingly, outside the enceinte (in great towns) there must be constructed, according to the formation of the ground, detached forts or strong lunettes, thrown out in an advance of from 500 to 800 paces, in order to command all the windings of the ground in front, and to restrict the enemy's attack to a distance of at least twice the width between the two parallels from the main fortification; also to afford powerful support to an effective garrison, which, instead of waiting passively, is ever on the look-out for opportunities of making advantageous sorties.

"This outer-strengthening must be applied particularly to the fronts that are accessible to an approach, and those works must therefore be especially considered which flank the field of attack, but which are secured by the natural obstacles of the ground from a direct attack by means of sap.

"If the interior of these works be provided with bomb-proof redoubts in the gorge, which are adapted for a flank defence such as we have just spoken of, and which cannot be destroyed by the enemy's silencing batteries; then the fronts, which were formerly accessible, may thereby be rendered nearly inaccessible.

"The object of the connected enceinte of the centre is more of a defensive, and that of the system of advanced lunettes more of an offensive nature; so that by uniting the two, all essential interests, both with regard to the defence and also all great operations of the befriending army relating to the fortress, might be realized.

"In Plate III. fig. 5, is represented, though only on a small scale, the fortification of a great 'place-d'armes,' surrounded by detached forts and lunettes, and is somewhat similar to the manner in which Cologne is fortified. The ground is level and approachable everywhere, on account of which the division of the advanced works has been pretty regular. From whatever side the place may be attacked, the successive capture of most of the detached works will be necessary before the besiegers can advance against the main-work itself; that is, provided in an attack directed against the upper or lower side of that part of the fortress adjoining the river, in order to avoid coming in contact with the branch-works on the right bank, the besiegers prefer attacking the more central fronts, in which case they would have to take the works (tinted) one after the other, to secure their approaches from being surrounded and enfiladed. And then the lunettes yet remaining to the fortress would, by increasing the length of front that is attacked, still give an unusual increase in strength to the fortification, and conduce much to the effect of sorties directed against both wings of the attack.

"If at the defence of Kolberg a single outwork, and of small extent, could delay the attack for weeks, how much more may we not expect from an energetic maintenance of a field of combat so well prepared as that we have just considered, and in which, only as a preliminary to attacking the strongest part of the fortress, seven independent sieges must take place in all their stages, and during which a great quantity of material must necessarily have been consumed by the besiegers; so that perhaps the probability of seeing their attacking operations arrested is not very distant; and, at any rate, the attack of the principal enceinte can then only be carried on with reduced forces and a confidence much diminished, to the evident advantage of the besieged.

"This consideration has further led to the question,—whether it would not be sufficient to protect the inner space of the fortified ground—the town and the military establishments in it—only against a coup-de-main, by enclosing it with a wall

simply loopholed and flanked by small caponnières, thus throwing the real strength of the defence entirely on to the chain of advanced detached works, and increasing, as much as possible, their capability of resistance, by employing all those means which, in the simple construction of the inner enceinte, were not made use of. This proposition also must certainly be condemned; for even if you can give the advanced works a somewhat greater absolute strength by increasing their extension, by giving them more covered batteries, by increasing the height of their walls, and giving them altogether an opportunity of developing greater forces,—yet, on the whole, no much more favourable result will be obtained than was to be expected from the other construction and disposition of the works, even without increasing their strength in the manner we have shown; for the counterscarp, the rampart with its flank defences, and the redoubt, will still have to be overcome, one by one, by means of sapping, artillery, and mines.

"Consequently, in strengthening single outposts at the expense of the principal enceinte lying behind them, on the one hand, all the benefit that was to be expected might not be obtained; and, on the other hand, it might produce this evil consequence, that after the taking of a few forts, the simple line of walls, only intended for a defence against a coup-de-main, would be breached in a few days by heavy artillery, and the duration of the siege would thereby lose twice as much time as may have been gained in the defence of the outposts.

"Neither would it be justified by tactics: as if, for instance, an army acting on the defensive were to employ the greater number of its men in the occupation and defence of the villages, farm-houses, and hedges lying in front of its position, and were to keep only a small reserve in its centre, which would not be strong enough to defend it in case a village were lost, and the enemy were to push on with an overwhelming force, and endeavour to break through the position.

"The main position, then, should always be strong enough to be able to maintain a siege with effect, even after the advanced outworks have been destroyed. *And the defence should gain in energy in proportion as that of the besiegers begins to slacken.*

"The principal enceinte should therefore be the strongest part of the position, unless particular circumstances in the formation of the ground render a deviation necessary.

"The question now arises, how the necessary independence of the different parts is to be applied to the formation of '*enclosed principal enceintes.*'

"This is to be effected by the most important points in the ground, which are to form the enceinte of the main position, being supplied with 'strong independent works, and connected by simple lines,' but which are to receive powerful flank defence from the redoubts, or from the covered batteries in the detached works: in fig. 4, Plate III., is represented a fort, such as has been actually constructed, and which will be sufficient to explain what has been said.

"The casemated principal redoubt of the fort, consisting of large defensive barracks and magazines, fully commands the interior space of the work, by means of its covered and open batteries. It overlooks every part of the enceinte in front: it stands in safe and immediate connection with the arrangements of the fortress for inundation, and also with the detached works,—forming thus a compact whole, which must be taken by a siege, if the enemy wishes to have unlimited possession of the whole position.

"The road leading to the attack of the redoubt is by the enceinte of the fort lying in front of it.

"The principal parts of which the latter consists are the seven casemated redoubts, marked black in the plan, and which constitute the main points of the position, and

as such, command the intermediate lines of communication, sweeping them both outside and inside.

"A fortification so constructed has this great advantage, that it can, in case of need, be maintained against superior numbers by a small force, which is then concentrated in the detached works. From the position of the redoubts with regard to the two straight faces of the fort, and which adjoin the principal one, it is immediately seen what great support they can give the latter by their flank fire; and it may be supposed that the greater half of the outer fortification, with its redoubts and flanks, must be laid in ruins before the crowning of the glacis of the principal redoubt can be effected.

"The enceinte, of which fig. 2, Plate II., represents a part, is organized entirely on similar principles.

"The principal redoubts, with their counterguards thrown out in front of them, and forming a bastion, are here the detached works, which occupy the principal points in a distance of from 700 to 800 paces of each other, and are connected by means of lines of retrenchment.

"This is the type of a fortification such as will be applied in the intended circumvallation of several large 'places-of-arms,' and some of which are now in course of construction, but only to those fronts subject to a regular attack. In this polygonal fortification the fronts receive a length of about 150 rods, or 620 yards, nearly, but in which the line of defence will not, as the flanking of the connecting lines proceeds from the redoubts in the centre, be longer than 75 rods, or 350 paces, and are consequently adapted for the use of case-shot as well as musketry. With seven such fronts, the same space might be enclosed as would be included in the dodecagonal bastion, consisting of polygonal sides only 90 rods long; whereby is obtained (independent of the disadvantage the latter has in not being able to afford sufficient defence to its lines) this important consideration, that the heptagon with large fronts (including the sweeping of the ditches in front of the counterguard of the redoubt) requires altogether only twenty-eight flank defences, while the dodecagon, with its bastion, requires forty-eight (including its ravelins), and giving each only two pieces of artillery, shows a greater expenditure by forty guns, with men to serve them.

"In the heptagon with large fronts, this increase can either be dispensed with, or else it can be applied to the strengthening of single flanks.

"The redoubt in the centre of the front, and which can be safely connected with the two caponnières of the ditches of its counterguard, unites in itself all the flank defences of the front,—sweeps, commands, and overlooks all its lines, both within and without,—affords, besides, covered places of accommodation for the men and stores,—and constitutes thus a separate strong redoubt, or citadel, on every front.

"Owing to the deep position of the flanking batteries, there are no places in the ditches which cannot be seen.

"Troops, with every description of arms, can be marched in sections along each front by two roads (as indicated in fig. 2, Plate II.); and these lead besides through the safely situated gates (at *a* and *b*) to the right and left of the redoubt into the main ditch,—from this convenient *appareil*, into the re-entering 'places-of-arms' of the covert-way, and from them again through the sally-port, on to the glacis.

"Eight columns can thus 'débouche,' at the same time, on the four adjoining fronts (without regard to any large gates that may exist), by which means any movement of troops can be effected, either for extensive operations, or for the purpose of a vigorous defence.

"Cavaliers, or 'casernes défensives,' are sometimes employed immediately in the rear of each front, which secure shelter for the troops immediately engaged in the defence of the fronts attacked,—as at Ingolstadt. *Vide* fig. 2, Plate II.

"Further, it will be seen, that the lines of the body of the place, which are constructed in as simple a manner as possible, are quite sheltered from enfilade; and that by extending them, sufficient room is gained to allow of the guns being moved at different periods of the siege.

"The length of the faces of the counterguards may be very effectually covered by means of *hollow traverses*,* which may be placed at the salients of these works, in the direction of the capitals, at H, in fig. 2. Such hollow traverses are situated in the masonry, and are quite sheltered from without: they project above the line of fire of the work only by a parapet 4 feet high; so that, seen from the outside, they look merely like common traverses. Their vault (or casemate, or gallery), under the rampart, presents a safe shelter for the men, and the upper part of them, lying on the rampart, will accommodate several heavy howitzers, or short 24-pounders, which, being completely sheltered, can fire over the parapet to the right and left, on to the ground of attack. As soon as the attack merges into the last period, and proceeds from the third parallel to the glacis of the counterguard, in order to effect lodgment there for the construction of counter and breaching batteries,—and when the attacking batteries are, from the position of the parallels and approaches, very much hindered from developing their full activity,—then the guns of the fortress take up the war again, with increased effect, as from 10 to 12 pieces of ordnance commence their fire now, quite unexpectedly, from the covered positions in each of the three or four main works overlooking the field of attack. Their position is better shown by the line H R, fig. 2: they stand sheltered partly in the hollow traverses in the salients of the counterguard, partly in the two stories of the redoubt, which are adapted for artillery, and of which the upper one lies high enough to sweep, by direct fire, the slopes of the glacis of the adjoining salients, as is indicated by lines of fire.

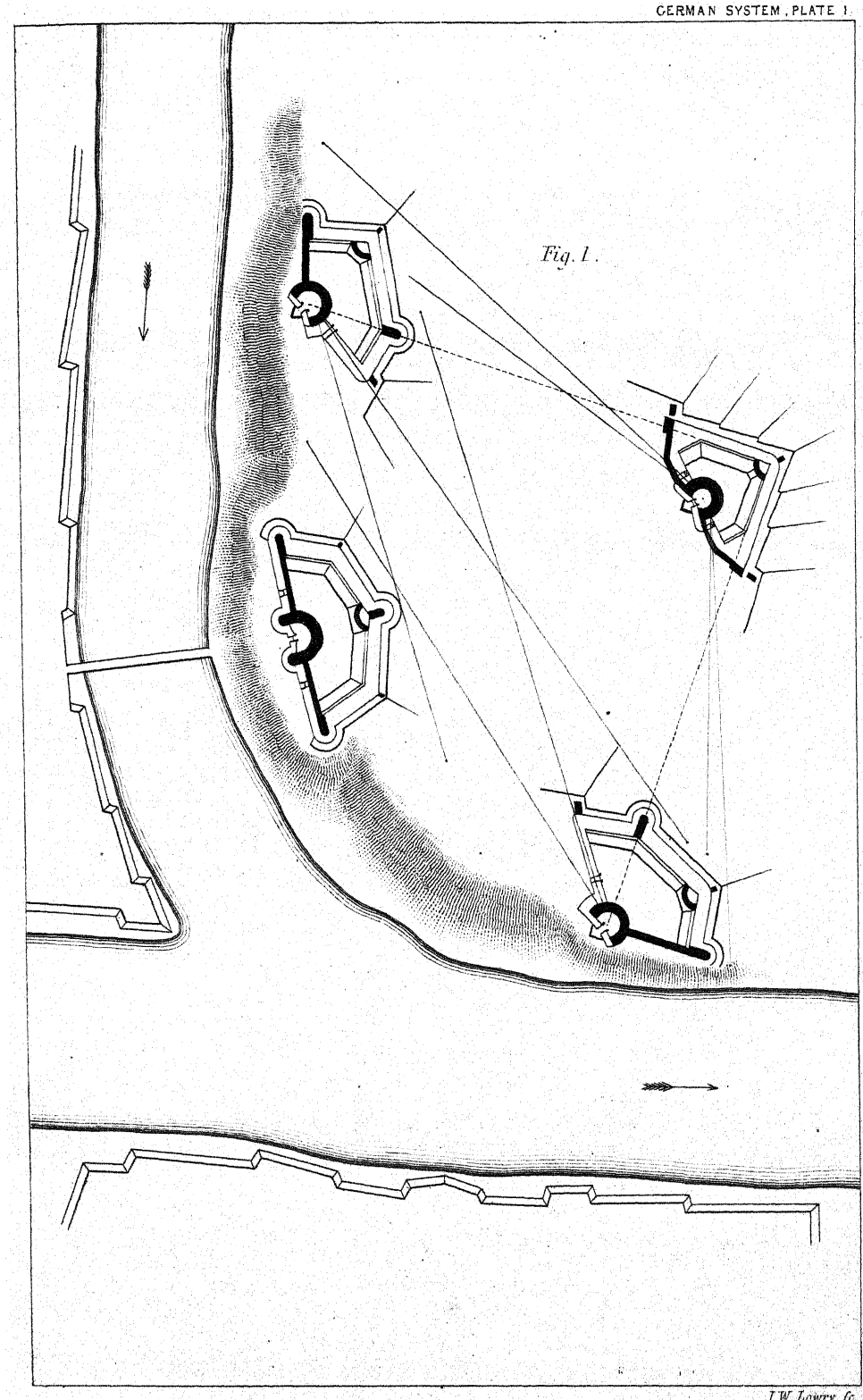
"The enemy's lodgments on the crest of the glacis are thus subjected to a flank and reverse fire from a position completely sheltered by the wall of the counterguard, which he will find great difficulty in counteracting. But if, notwithstanding these difficulties, the besiegers did succeed in erecting counter-batteries, and were also determined, in spite of the flank and reverse fire which cannot be silenced, to destroy the flank defences of the front, they would then be opposed to a superiority of twice their number of guns, half of which are situated in covered positions in the caponnières of the ditches, or in the casemated flanks. Therefore it is hardly possible that they should succeed in their object by the use of artillery alone: a lodgment on the salient of the wall of the counterguard would better be effected by mining, which is a much slower process, and is so liable to be counteracted by a well prepared garrison. But suppose it to be accomplished; then, from this confined basis ('where the ruins of the hollow traverse that is destroyed hardly allow of a narrow obstruction being thrown up, and which is every moment liable to be blown up by countermines,') the attack must be directed against the very strongest part of the front,—against the redoubt itself with its superior fire; also against that part of the body of the place (*haupt-wall*) that adjoins the redoubt, and which is as yet entire.

"And if, even after this, the redoubt should be taken, the enemy will only be in possession of this single work.

"Therefore in this system of fortification, to end the whole siege by one blow (as could be done under the bastion system) is utterly impossible.

"The garrison retains possession of all the other detached works, whose redoubts can each maintain a separate siege, and stand in safe and intimate connection with

* "Hohltraversen."



J.W. Lowry fc.

John Weale, 59, High Holborn. 1847.



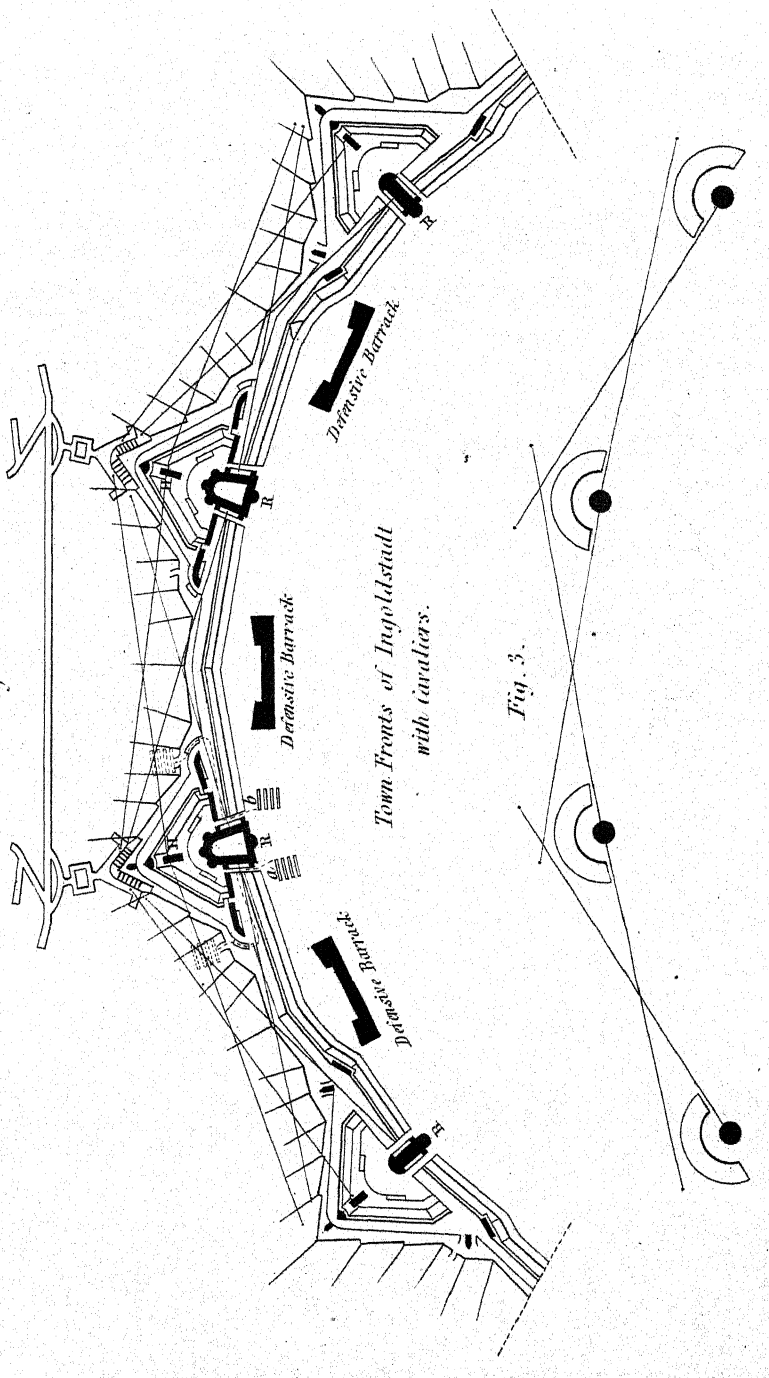


Fig. 2.

Town Fronts of Ingolstadt with cavaliers.

Fig. 3.

J. W. Lowry fo.

John Weale, 59, High Holborn, 1847.

Fig. 4.

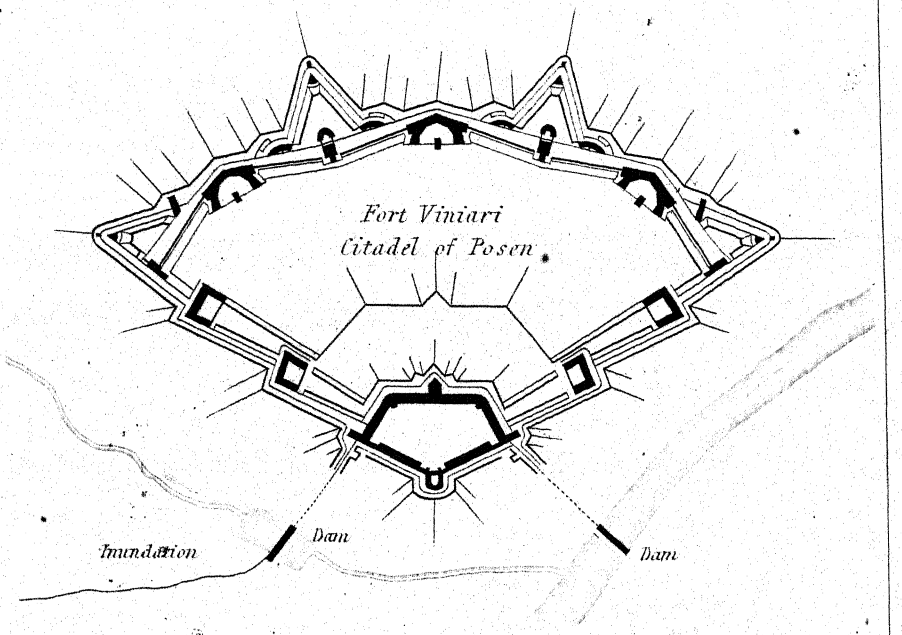
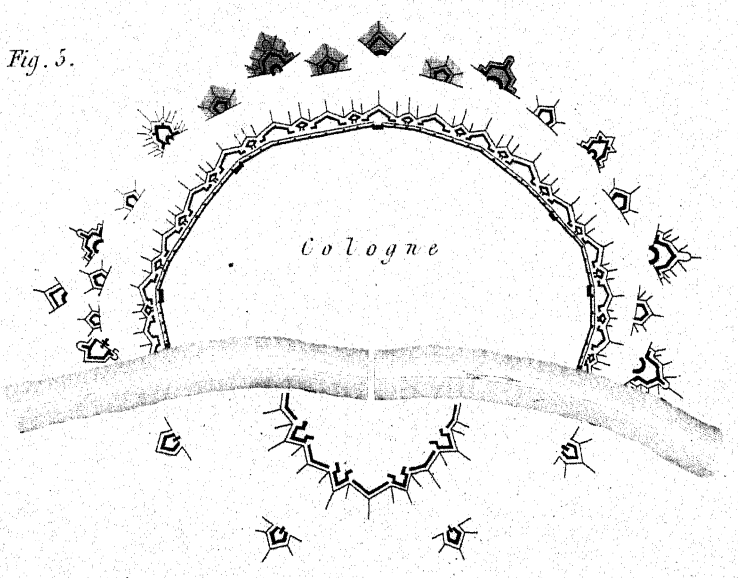
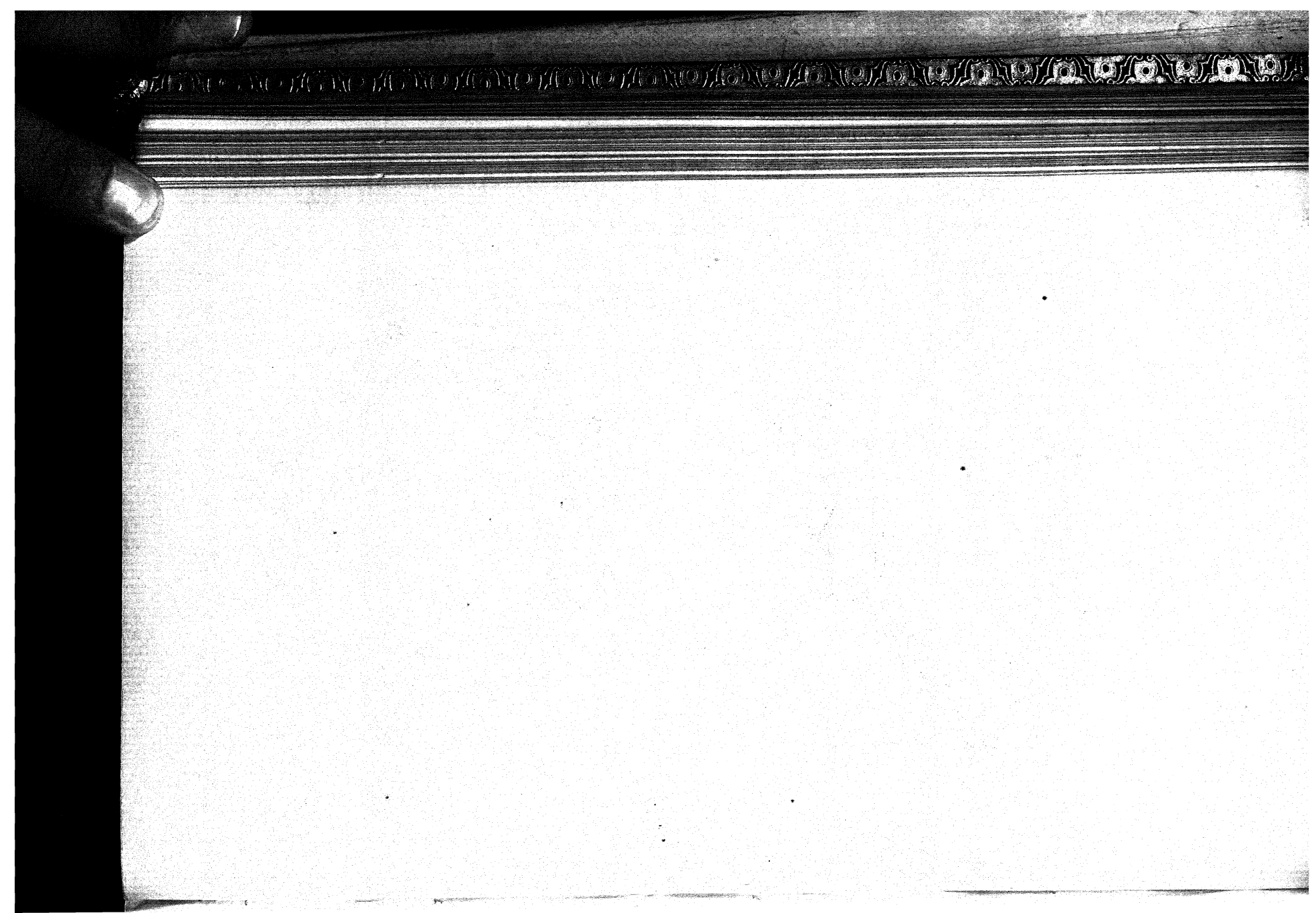


Fig. 5.



J.W. Lowry fc.

John Weale, 59, High Holborn. 1847.



each other; and it can therefore, 'by means of these small citadels, which command those streets and parts of the town which are near them,' carry on the defence to the very last.

"These are the general principles which characterize our new fortifications,—these the objects which determine their disposition, and which were suggested by Vauban and Sorwigai,—better understood by Rimpler,—were defined by Montalembert,—and lastly, confirmed by experience in warfare, as being the desired attainments.

"The objects of the new fortification are principally to remedy the evident defects in the 'System of Bastions,' which have been obviated by the introduction of independent and detached works, also of covered batteries, which cannot be destroyed from without,—of bomb-proof places for the troops in the works themselves, and also in those positions where they are required for the defence,—by the construction of advanced and detached outposts,—and lastly, by establishing practicable and safe communications for all movements of troops.

"If these principles have been the leading ones, in the newly constructed works of fortification, still there has been no *fixed system* observed by us.

"An incalculable number of places have been systematically constructed with the *same trace and profile*, and supplied with the same outworks, without regard to whether any part of them was on unapproachable ground, and liable to a regular attack or not.

"What a saving might here have been effected, or how might other parts have been strengthened, without additional expense, if the unapproachable fronts had been merely secured against a coup-de-main, and the means thereby spared had been applied to the fronts that were liable to be attacked, or to the advanced outposts!

"BRÈZE,
"General Major and Engineer Inspector."

OBSERVATIONS ON THE NATURE OF FORTRESSES, IRRESPECTIVE OF SYSTEMS.*

The value of fortresses without reference to systems is more difficult to define. Fortification has been noticed in this work, as *Field Fortification* and *Permanent;* as also the system of mines, with the several accessories. In the second relation it is proposed to consider the value of fortification simply as affording cover to the few or many who desire to protect themselves from a superior force,—superior either in means or numbers. The various contrivances now adopted in war are given in this work, from the *pah* of the New Zealander, and Turkish mode of entrenching themselves with pick and shovel and felling-axe for converting the resources of the spot for immediate defence, to the more complicated means of the *abbatis*, *stockades*, *fougasses*, and *trous-de-loup;* thence to the *place du moment*, to the *entrenched camp* and *position*, and to *fortresses*.

The application or misapplication of these resources, as ignorance or pedantry have dictated, gives a fortuitous and meretricious importance to places; and so it often occurs that places of inferior merit obtain a character foreign to the original design;—as, for example, Burgos, a mere field-work, being attacked by theDuke of Wellington with inadequate means.

The value of fortified places, from the siege of Syracuse by the Athenians to that of Sebastopol in 1855, has little reference to systems; hence the difficulty of esti-

* By Major-General Lewis, C.B., R.E.

mating their value, if the position, object, and facility of being attacked are not well appreciated. We see every day expensive works built for an inferior purpose, although the fortifications are the best of the kind. Again, we perceive important positions occupied by very inferior works. Again, we see fortresses of great importance, and of vast expense in execution in one war, of no value in the next. Then comes the clamour of what is the use of fortification, and the great reluctance to expend money upon them. And a fort or fortress may, by its position, have a value far above its merits as regards construction, by the impracticability or extreme difficulty of attacking, or even investing it: we may quote Sebastopol as an example. Notwithstanding the celebrity of the siege, the works were not constructed after any system, being merely formidable breastworks, well armed, adapted to the contour of the ground,—somewhat after the Roman encampment we may now see between Dorchester and Weymouth,—supported by a large and well-disciplined army.

Here it may be observed that the English engineers advocate no particular system, and are willing to follow any suited to their purpose, having perhaps some opinion of the *Bastion System* in its primitive construction, with its lines of defence,—so that no part should be left unseen, its deep ditches, and counterscarp, and glacis,—and are disposed to eschew the many expedients and contrivances dictated by pedantry and involving expense, which cause distrust in the value of the art.*

Hence the necessity of returning to that school of which the great Vauban was the master, and studying his projects and schemes of defence, considering:—First the object in view, whether temporary,—that is, if for the object of the war or for the campaign,—defensive or offensive, or for tactical operations of the moment; or whether as a permanent defence against a power always aggressive, and ready and able to take advantage of the weakness of a rival power. Secondly (a point of very great importance, and not often well considered), the facility of affording succour in time, either in men, communication, or provisions, according to its internal resources. Even the strongest fortress may succumb if not relieved by sea or land, and therefore the position of a fortified place should be taken up in reference to this condition: an inaccessible point is of little value unless it can be relieved. But relief may be accomplished in two ways: by a more powerful force than the besiegers, or by stratagem, or by the change of seasons rendering the blockade or siege no longer possible, as in the rainy season in India; or by intense frost, as in Canada. Food, being a perishable article, cannot be depended upon beyond a certain period, and store-room can only be given for a limited supply; so that when we propose to make a place impregnable, the possible relief must be considered. Thirdly, the position, with regard to the nature of the ground, has to be considered. Thus wet ditches are best for low ground: for which we may consult Coehorn, and the suggestions of modern Dutch engineers. Then, if the ground is mountainous or precipitous, the bastion system becomes inapplicable, and next are suggested the systems of reverse fire with short flanks; and if the plateaux are narrow, en tenaille with casemates for guns. Or we may follow the German system, or that of Carnot, or mere straight lines, polygonally, following the contour of the ground, with advanced works open in the rear, at such distances as the ground offers favourable sites, without reference to equal distances, or arbitrary rules for lines of defence; the improvements in artillery and musketry rendering it practicable to extend the lines of defence 200 to 400 yards. In all cases, the application of countermines will add greatly to the period of defence. Lastly, comes the question of cost, the expense being guided by the considerations of object of the proposed fortification, capability of being

* With many there is a growing appreciation of the German System, in its general character. —Ed.

relieved, and nature of ground; as, for example, no expense laid out upon either Portsmouth or Dover can be too great, whilst fortifying Edinburgh should be the minimum of defensive works, such as barricades and loopholes, against the possible attack from Russia. The engineer should not be led astray by his ingenuity and skill in the construction of works, and so entail an expense quite at variance with the circumstances of the case. Whether the place be large or small, an ample supply of water is necessary, with good cover for the men and stores. The emplacement for artillery should be well chosen, so as to obtain, at least at first, a superiority of fire. If the points adverted to in the value of fortresses and fortified places are not well considered, the art gets into disesteem, and governments are unwilling to incur the responsibility of expending large sums, sometimes for objects of little value. And yet forts and fortresses become valueless under circumstances over which the engineer had no control or which he could not foresee, such as the extension or alteration of a line of frontier; but this rarely applies to maritime frontiers. Prolonged defence, or rather duration of resistance, has not been taken into account, from the uncertainty of calculation of the resources of an enemy. A prolonged resistance is sometimes gained by the want of means and skill of the besiegers; or, *vice versâ*, a powerful enemy, with every resource at his command, can bring the resistance to the minimum of time. And a false position of a fortified place may reduce it to the latter alternative, whilst in another it would become almost impregnable;—as, for instance, Pampeluna in Spain; whereas Radstadt in Central Germany, near the Rhine, where so much money and skill have been expended, may, by its position, be taken in a few weeks, because it is so placed,—within a day's march of Strasburg, a fortress containing every means of attack, being a vast depôt of artillery and every resource necessary for siege operations.

G. G. L.

APPENDIX A.*

Report of Experiments carried on at Woolwich in 1822, *against Carnot's Detached Revetment.*

In the summer of 1822, the Duke of Wellington being Master-General of the Ordnance, it was determined to make experiments on the possibility of breaching walls protected by earthen counterguards, as proposed by Carnot, in his System of Defence, by firing over the crests of such counterguards.

It was first desirable to ascertain the smallest elevation at which shot could be fired, if it were practicable to throw shot at all, which, clearing the counterguard, should fall sufficiently in their flight between it and the wall to strike the latter low enough to open a practicable breach, and what charge and elevation were most suitable for this purpose; and next it was to be determined whether shot so thrown had sufficient momentum to ruin masonry.

Experiments were accordingly made, with the first object, in twenty-eight days, between August 2nd and September 24th, 1822, by firing over a bank of earth 66 feet long, and in section similar to the upper part of Carnot's counterguard, having its crest 12 feet above the level of the experimenting batteries. The distances from the top at which the different shot would have struck the wall, were known by the height at which they struck a bank of earth thrown at the proper distance (60 feet) in rear of the counterguard; and for those which struck the ground between the two mounds, by measuring the distance from the foot of that in rear; and all which were stated to strike lower than 12 feet were thus obtained.

The details of the experiments are given in the following Table:—

* From the second volume of 'Corps Papers.'

Results of Experimental Practice made at Woolwich in August and September, 1822, to ascertain whether it would be practicable to fire shot over Carnot's Counterguard, and strike the Wall in rear low enough to open a Breach.

Days of Practice.	Date.	Nature of Ordnance.	Range.	Charge.	Elevation.	No. of rounds.	Shot or Shells struck the wall from top, at												Total.	Proportion		
							1 to 2 feet.	2 to 4.	4 to 6.	6 to 8.	8 to 10.	10 to 12.	12 to 14.	14 to 16.	16 to 18.	18 to 20.	20 to 22.	1 to 12.	12 to 22.		Of rounds which struck the wall.	Of those striking the wall that struck below 12 feet.	Of the whole number of rounds fired that struck below 12 feet.
				lbs. oz.																		
3rd.	Aug. 7.	24-pounder iron, 9 ft.	400 yards.	0 12	10	37	2	5	...	1	...	...	...	...	...	...	...	8	...	8	more 1-5th.		
5th.	9.	Do. do.		1 0	9¾	30	3	2	1	...	4	1	...	...	...	...	...	11	...	11	more 1-3rd.		
9th.	16.	68 carronade wt. shot.		1 0	9¼	30	4	2	1	2	1	2	...	...	...	...	...	12	...	12	2-5ths.		
				1 0	9¼	20	...	2	4	...	2	2	...	...	...	...	...	10	...	10	1-half.		
10th.	19.	Do. do.		1 4	7½	30	...	2	...	6	...	2	...	...	...	...	...	10	...	10	1-3rd.		
				0 14	11½	20	1	...	...	...	...	3	...	1	...	...	...	4	1	5	1-4th.		
21st.	Sept. 4.	Do. do.		1 0	9¼	40	...	2	4	2	...	1	...	...	...	...	...	9	...	9	near 1-4th.		
26th.	Aug. 27.	8-inch iron howitzer.		1 6	10	40	3	2	1	1	2	1	...	...	...	...	...	10	...	10	1-4th.		
		Total, not exceeding 11½° elevation at 400 yards range.	400	...	...	247	13	17	11	12	9	12	...	1	...	...	...	74	1	75	more 3-10ths.	1-75th.	
4th.	Aug. 8.	24-pounder iron, 9 ft.	500 yards.	0 9	10¾	40	2	...	1	2	...	1	1	...	...	...	...	6	1	7	more 1-4th.		
6th.	12.	8-inch iron howitzer.		1 4	9½	40	...	2	...	1	1	2	...	...	...	...	...	6	...	6	more 1-7th.		
7th.	13.	Do. do.		1 8	7½	20	1	...	...	...	1	...	...	...	...	...	...	2	...	2	1-10th.		
		10-inch do.		2 0	10¼	30	2	1	2	1	2	2	1	...	...	...	...	10	1	11	more 1-3rd.		
8th.	14.	Do. do.		1 10	9½	30	3	1	3	3	2	1	...	...	...	...	...	13	...	13	more 2-5ths.		
11th.	20.	68 carronade wt. shot.		1 4	9	40	2	3	2	4	1	2	2	...	...	...	...	14	2	16	2-5ths.		
15th.	26.	8-inch iron mortar.		1 11	10	40	...	5	2	1	2	1	...	...	...	...	...	11	...	11	more 1-4th.		
		Total, not exceeding 10¾° elevation at 500 yards range.	500	...	...	240	10	12	10	12	9	9	4	...	...	...	...	62	4	66	more 1-4th.	1-16th.	
		Total, not exceeding 11½° elevation.	...	...	...	487	23	29	21	24	18	21	4	1	...	...	...	136	5	141	more 2-7ths.	1-28th.	1-97th.

Results of Experimental Practice made at Woolwich in August and September, 1822,—continued.

Days of Practice.	Date.	Nature of Ordnance.	Range.	Charge.	Elevation.	No. of rounds.	Shot or Shells struck the wall from top, at												Total.	Proportion		
							1 to 2 feet.	2 to 4.	4 to 6.	6 to 8.	8 to 10.	10 to 12.	12 to 14.	14 to 16.	16 to 18.	18 to 20.	20 to 22.	1 to 12.	12 to 22.		Of rounds which struck the wall.	Of those striking the wall that struck below 12 feet.	Of the whole number of rounds fired that struck below 12 feet.
				lbs. oz.																		
12th.	Aug. 21.	8-inch iron mortar.	400 yards.	1 0	15 elevation.	20	...	...	2	...	...	2	1	2	4	...	...	4	7	11	more 1-half.		
13th.	22.	Do. do.		1 0		40	1	2	...	2	...	1	2	1	1	2	...	6	6	12	3-10ths.		
17th.	28.	8-inch iron howitzer.		0 11		50	5	2	4	2	1	7	1	1	1	...	...	21	3	24	near 1-half.		
22nd.	Sept. 16.	Do. do.		0 11		30	1	...	2	3	1	...	2	1	2	...	1	7	6	13	more 2-5ths.		
23rd.	17.	16-inch do.		1 3		30	...	...	1	1	1	2	1	3	2	...	2	5	8	13	more 2-5ths.		
24th.	18.	Do. do.		1 2		30	...	...	1	4	1	...	1	1	2	...	3	6	7	13	more 2-5ths.		
20th.	3.	68-pr. carron wt. shot.		0 11		40	3	1	3	4	...	2	1	...	2	...	...	13	3	16	2-5ths.		
25th.	19.	Do. do.		0 13		30	...	1	3	1	3	1	...	1	...	3	...	9	4	13	more 2-5ths.		
		Total, at 15° elevation and 400 yards range.	400	...	15	270	10	6	16	17	7	15	9	10	14	5	6	71	44	115	near 3-7ths.	near 2-5ths.	
14th.	Aug. 23.	8-inch iron mortar.	500 yards.	1 5	15 elevation.	40	1	1	1	1	...	...	3	3	...	1	1	4	8	12	3-10ths.		
18th.	29.	8-inch iron howitzer.		0 14		40	...	...	2	1	4	1	3	1	...	...	...	8	4	12	3-10ths.		
28th.	Sept. 24.	Do. do.		0 14		30	1	...	...	...	1	...	...	...	2	...	1	2	3	5	1-6th.		
27th.	23.	10-inch do.		1 8		30	2	...	...	...	2	3	2	1	2	1	1	7	7	14	near 1-half.		
19th.	2.	68-pr. carronade shot.		0 13		40	1	1	...	2	...	2	3	2	2	1	...	6	8	14	more 1-3rd.		
26th.	20.	Do. do.		1 0		30	1	1	1	1	1	1	...	...	...	...	1	6	1	7	near 1-4th.		
		Total, at 15° elevation and 500 yards range.	500	...	15	210	6	3	4	5	8	7	11	7	6	3	4	33	31	64	more 3-10ths.	near 1-hlf .	
		Total at 15° elevation.	...	...	...	480	16	9	20	22	15	22	20	17	20	8	10	104	75	179	near 3-8ths.	near 3-7ths.	5-32nds.
		Total.	...	...	...	967	39	38	41	46	33	43	24	18	20	8	10	240	80	320	about 1-3rd.		

The first two days were considered as preliminary, consequently their practice is not included in the preceding Table: from the results of the others it was decided, that with elevations of 10° and 11°, it was not possible to strike the wall lower than 16 feet from the top; that only $\frac{2}{7}$ths of the shot and shells so fired would take effect upon the wall at all; and of those that did, only about $\frac{1}{28}$th at more than 12 feet from its top, or $\frac{1}{97}$th of the whole number, fired. This opinion was formed after 487 rounds from different descriptions of heavy ordnance had been fired, at ranges of 400 and 500 yards, with elevations not exceeding $11\frac{1}{2}$°.

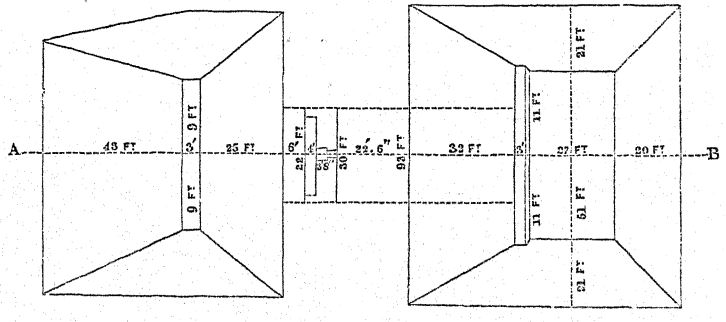
Four hundred and eighty rounds, at similar ranges, were fired at elevations of 15°; and it appeared that between $\frac{5}{7}$ths and $\frac{3}{8}$ths would have taken effect, of which $\frac{3}{7}$ths, or $\frac{1}{8}$th of the whole number of rounds, would have struck the wall lower than 12 feet from its top.

Of the 967 rounds, only 144 fell short; and of the 503 rounds remaining unaccounted for, it was considered that all except 37 would have struck the bastion in rear of the wall, if, according to the arrangement of Carnot's system, such work had been constructed there.

The experiments having proved that shot or shells could be fired at angles of 15°, so as to strike the wall, even at its foot, it remained to be determined whether, when so fired, their momentum was sufficient to breach it, the small charges necessarily used to attain the first object rendering this doubtful.

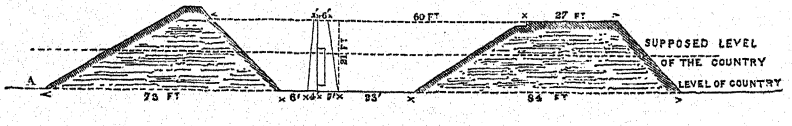
A portion, 30 feet in length at bottom and 28 feet at top, of a wall corresponding to that proposed by Carnot, was accordingly built with bricks, in the summer of 1823.

Fig. 1.—Plan of the Rampart, Wall, and Counterguard.



It was 21 feet high, 6 feet thick at top, 7 feet at bottom, and one loophole in a recess; to support which, in continuation, it was strengthened by a buttress, 4 feet square, at each end, the whole carefully built and well cemented.

Fig. 2.—Section on the line A B.



An earthen counterguard was thrown up in front, and a mound in rear, the former being at the same distance and having the same section as that proposed by Carnot:

the latter represented his bastion, being at the same distance, but was only carried up 4 feet higher than the wall, and was therefore 8 feet lower than that proposed by him.

On the 5th of August, 1824, a year after the completion of the wall, eight 68-pounder carronades, in battery 500 yards from the crest of the counterguard, three 8-inch and three 10-inch iron howitzers, at a distance of 400 yards,—in all fourteen pieces,—fired 100 rounds each in about six hours, the howitzers firing live shells filled with powder, and the carronades solid shot.

A practicable breach, 14 feet in width, was made by their fire, and the buttresses were much injured (see figs. 3 and 4).

Fig. 3.—Front View of the Wall, showing the effect of the first and second day's fire.

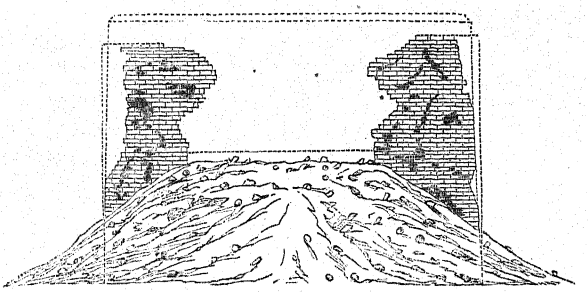
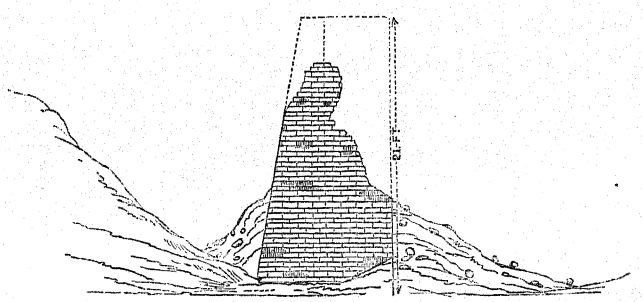


Fig. 4.—Side View of the Wall after the second day's fire.



The splinters of the shells proving inconvenient to the men in the nearer battery, the loading of the shells was diminished.

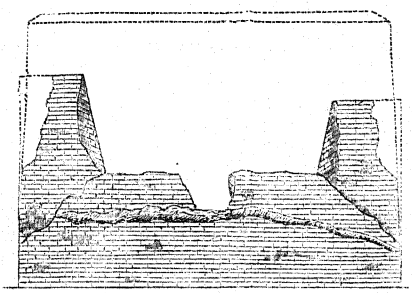
On the 6th of August the firing recommenced from eight 68-pounder carronades, at 500 yards; two 8-inch iron howitzers, and four 10-inch ditto, at 400 yards: 50 rounds per piece were fired in two hours, when the breach was examined, and found to be complete in every respect, and the buttresses to be in the ruinous state shown by the darker shades of figs. 3 and 4.

On the 5th and 6th of August, two of the 8-inch and two of the 10-inch howitzers, and four of the carronades, had been placed on high traversing platforms, so as to raise them nearly to the natural level of the country, according to Carnot's system; but His Grace the Master-General, who examined the breach at this period, having

given directions that all the ordnance should be placed on common or ground platforms, the use of the traversing platforms was discontinued. It had previously been observed that no advantage or superior accuracy of fire attended raising the guns.

His Grace also ordered that the rubbish should be cleared from the breach; and it was found that the wall was about 5 feet in perpendicular height in front, with a rounding of rubbish of about $2\frac{1}{2}$ or 3 feet at top, and about $8\frac{1}{2}$ or 9 feet in height towards the rear (fig. 5).

Fig. 5.—Front View of the Wall when the Rubbish was cleared away from the Breach, after the second day's fire.



On the 11th of August the batteries recommenced their fire from eight 68-pounder carronades, at 500 yards, and six 10-inch howitzers, at 400 yards; when 85 rounds from each howitzer, and 100 rounds from each carronade, were fired in three hours and a half, by which time the wall and buttresses were one mass of ruin (see figs. 6 and 7).

Fig. 6.—Front View of the Wall after the third and last day's fire.

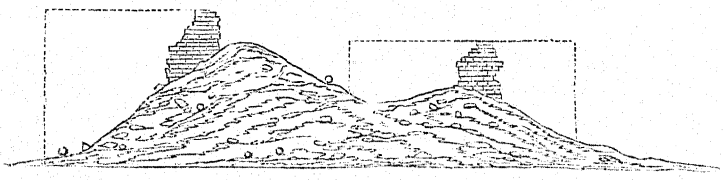
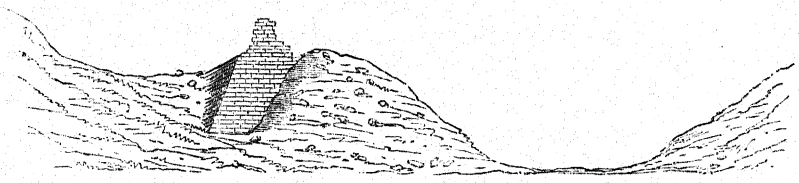


Fig. 7.—Side View of the Wall after the third day's fire.

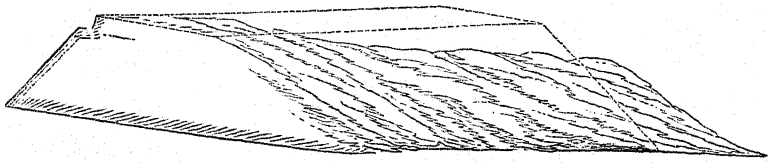


The charge of the shells had been so much reduced, to avoid splinters reaching the batteries, that a considerable number did not burst.

From careful observation, it appeared that about one-fourth of the shells and one-fifth of the shot struck the wall.

The increased rapidity of fire is remarkable, that of the third day being nearly double that of the first, although the reduction in the height of the wall, from 21 to 5 feet, rendered the operation obviously more difficult. A sketch of the counter-guard (fig. 8) shows the effect of the shells on its superior slope.

Fig. 8.—General View of the Counterguard in front of the Wall after the last day's fire.



W. D.

FOUGASS.*

COMMON FOUGASSES.

Fougasses Ordinaires.—These are small mines made by simply placing a box of powder at the bottom of a pit excavated for the purpose, from 3 to 4 yards deep. They are usually fired by means of an auget led up the side of the pit, and then parallel to the surface of the ground, at a depth of from 2 to 3 feet.

The bottom of the pit should be made firm; the box containing the powder and the auget well pitched over, to keep out the damp; and in filling up the pit again, care should be taken that the earth is well rammed, and the ground around turned up for some distance, so that nothing may indicate the position of the fougass.

SHELL FOUGASSES.

Fougasses à Bombes.—These are formed by burying shells which are connected together so as to explode simultaneously, either in the place where they have been lodged, or as they come to the surface of the ground. The shells are placed in the upper part of a box, which is divided horizontally by a partition with holes in it, to allow the fuzes of the shells to project down through them.

In the lower part of the box sufficient powder may be placed to project the shells to the surface of the ground; or in case it is intended that they should explode where they are lodged, the powder hose may be connected directly with them. These are principally used for the defence of the glacis, and are represented in figs. 1, 2, and 3, in the Plate.

Single shells may also be used: in this case the

8-inch should be placed 3 feet deep,
10-inch „ „ 5 „
13-inch „ „ 6 „

STONE FOUGASSES.

Fougasses Pierriers.—An excavation, in the form of a frustum of a cone or pyramid, corresponding nearly with the form of the entonnoir of the intended fougass, is made; and a box of powder, to project the stones or other projectiles with which the excavation is to be filled, is placed under a 2 or 3-inch board at the bottom of it. The axis of the excavation should be inclined to the horizon at an angle of about 40°, and the sides inclined to the axis at an angle of 24°. Care should be taken that there is sufficient weight over the fougass to make the line of least resistance correspond with the axis.

As the effect of these mines is nearly the same whether the conical form is adopted or that of the frustum of a pyramid, and as this latter offers great advantage from the simplicity of its form and the greater rapidity of execution, it has not been

* By Lieutenant-Colonel James, R.E., F.R.S.

thought necessary to give directions for the construction of the ellipses of the former.

Figs. 7 and 4 represent the plan and section of a fougass, which, with a charge of 60lbs. of powder, will throw from 3 to 4 cubic yards of bricks or stones from 40 to 50 yards, spreading over a nearly equal breadth.

In no case should more ground be broken than is absolutely necessary. If it is firm, an excavation may be made at once, of the form indicated in fig. 5; but if the ground is bad, the back should be revetted with sods, as in fig. 8. The auget is placed in a trench of about 1 foot wide by 2 feet deep.

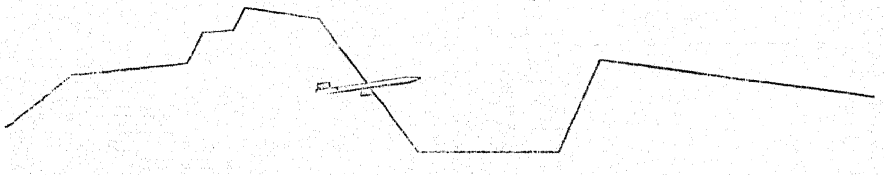
Figs. 5 and 6 represent the plan and section of a fougass, in which the back, sides, and bottom are made of plank, of the dimensions given. In bad ground, this is a good plan; indeed it is advisable to use wood for the support of the back wherever there is under-cutting.

This plan was tried experimentally at Athlone, in 1843. It is very readily executed, and produces a very good effect.

Figs. 8 and 10 represent the method which is used when it is not wished to charge the fougass till just before it is intended to fire it. In other cases the powder-box is slipped down a sort of shoot, which is immediately filled with sand-bags; and the pit in rear of it, as well as the trench for the auget, filled in with earth.

Fig. 9 represents a method by which a more *rasante* fire may be obtained, and which might be employed for the purpose of flanking ditches. In this case the axis is inclined about 20° to the horizon; the sides are inclined to each other at an angle of 45°. A revetment of sods is represented, for the purpose of confining the charge to the direction of the axis.

FRAISE.—*Fraises* are palisades laid horizontally, or nearly so, and they are fixed together in the same way: they have been usually placed on the berm of works, and may be considered the smallest obstacle for defensive purposes; they are, besides, expensive, and difficult of execution, and are therefore rarely applicable to field-works, and can only be fixed in permanent fortification advantageously, as explained in the diagram.



It has been found by experience,* that the fraise, in escalading works, serves as a footing rather than an obstacle, when placed on the berm.

When works are not revetted, and the exterior slope, as above, is at an angle of about 45°, and accessible, the fraise may be applied if flanked by a caponnière. (See also the Article 'Caponnière.')

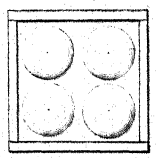
G. G .L.

FURNACE, SHOT.†—(*See* 'SHOT FURNACE.')—The furnace at present in

* See Jones's 'Sieges,' vol. i. page 175, third edition, and fig. 12 to Article 'Escalade.'

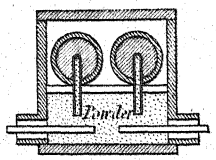
† The results obtained in actual practice are far below those given in the experiment, great difficulty being experienced in attaining anything like a white heat. Improvements have been suggested, but no substitute is yet adopted.—ED.

Fig.1.



Plan

Fig.2.



Section

Fig.3.

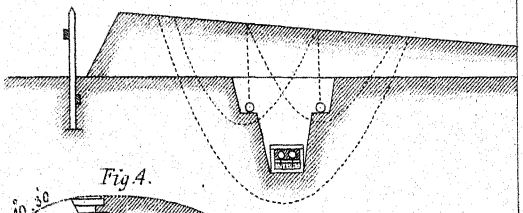


Fig.4.

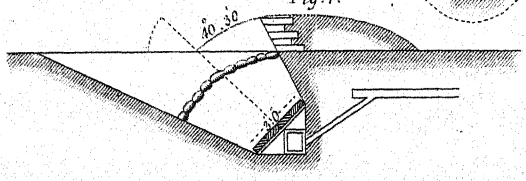
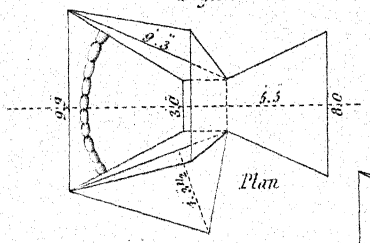
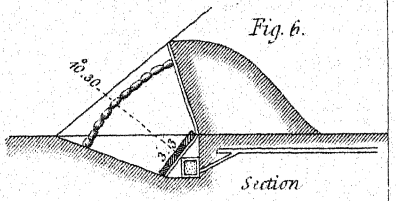


Fig.5.



Plan

Fig.6.



Section

Fig.7.

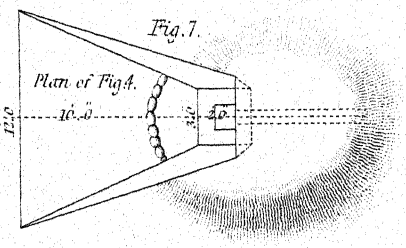


Fig.8.

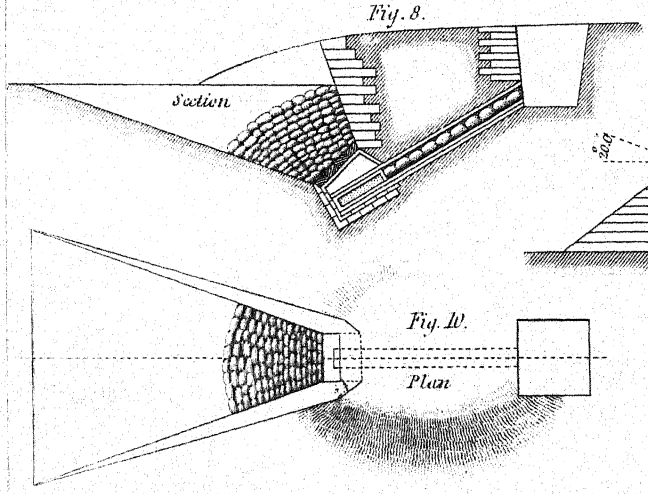


Fig.9.

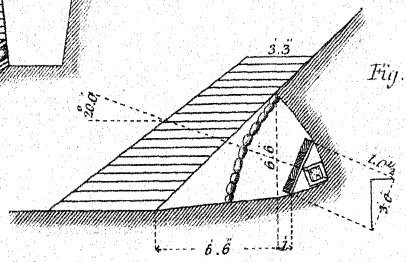


Fig.10.

Plan

Scale for Figs.1&2.

0 .5 1 2 3 4 5 feet

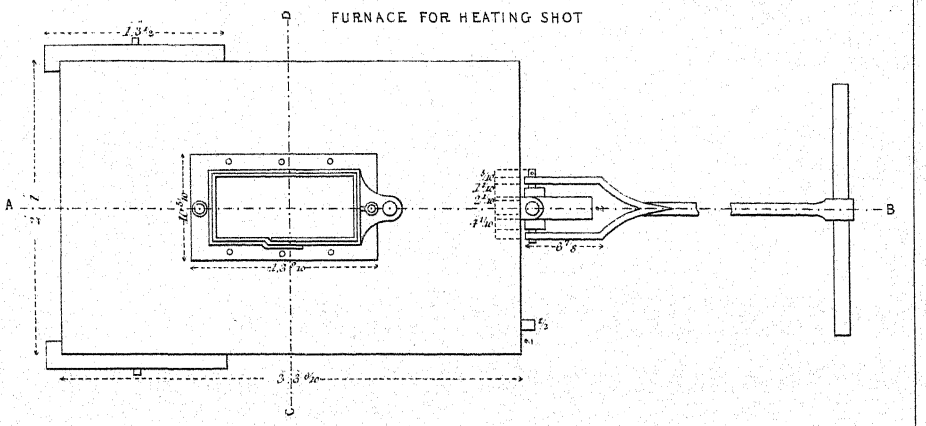
Scale for Figs.3.4.5.6.7.8.9.& 10.

0 5 10 15 20 25 feet

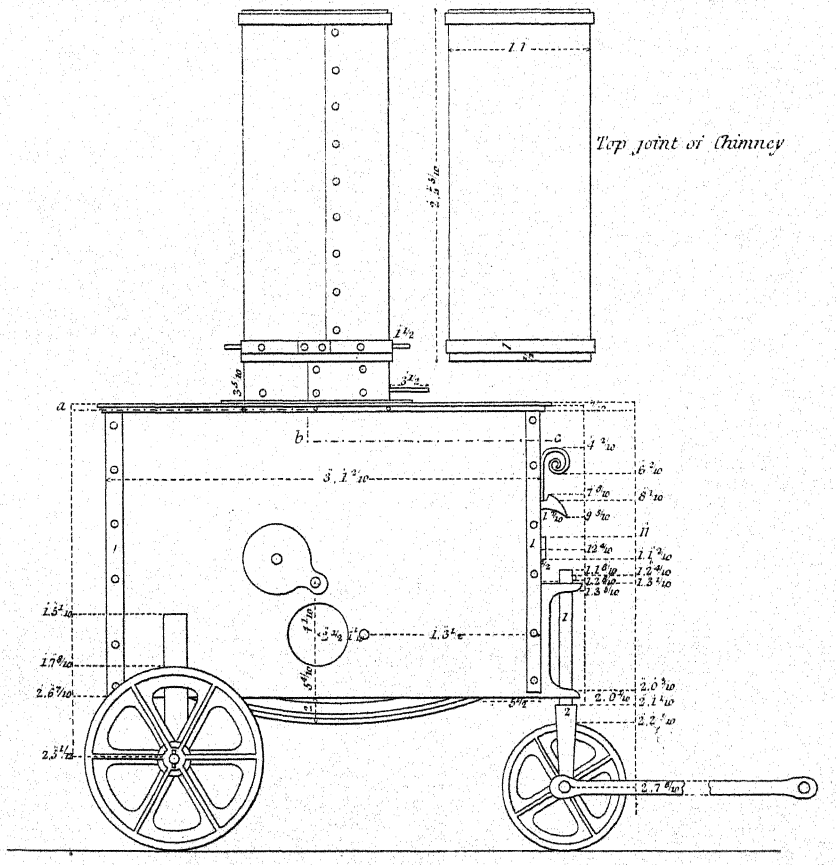
J.W.Lowry fe.

John Weale, 59 High Holborn, 1847.

PLANS SECTIONS AND ELEVATIONS OF CAPTN ADDISONS FURNACE FOR HEATING SHOT



PLAN



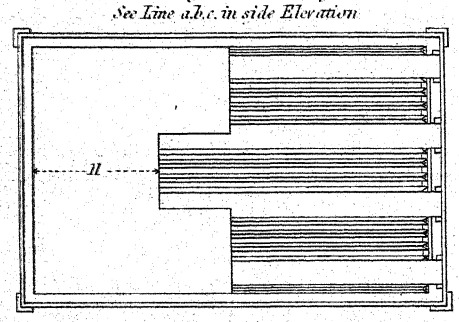
SIDE ELEVATION

J.W. Lowry fc

London, John Weale 59 High Holborn 1847.

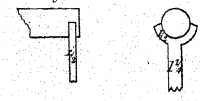
WROUGHT IRON TRAVELLING SHOT FURNACE

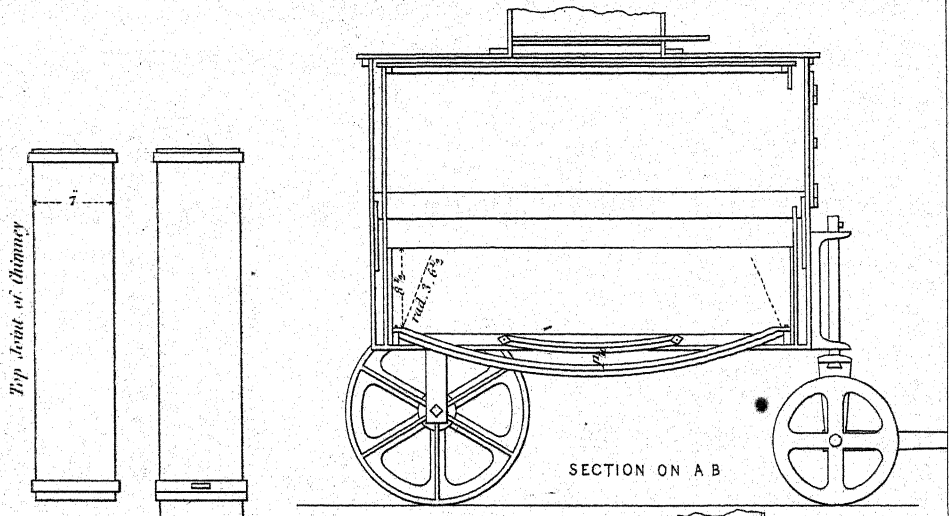
Plan showing interior arrangement
See Line a.b.c. in side Elevation

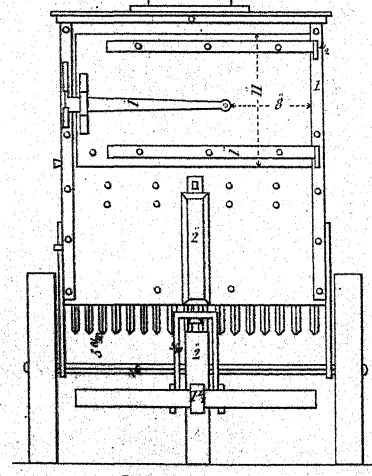


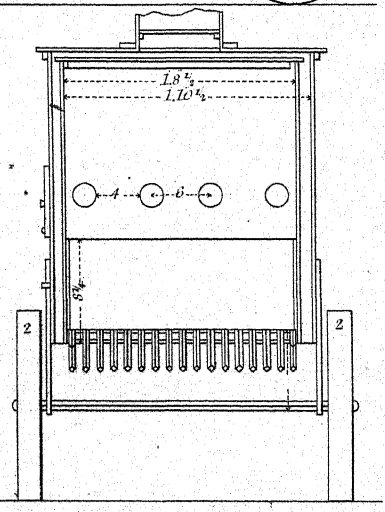
Royal Arsenal Woolwich
July 1846.

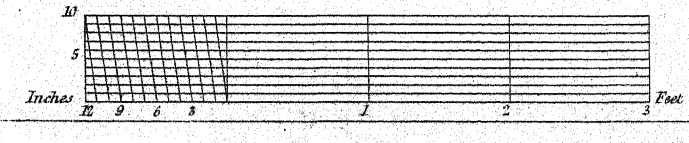
Mode of supporting the Iron Cylinder Shot Box











J.W. Lowry fc.

London. John Weale. 59 High Holborn. 1847.

use is of wrought iron: the exterior dimensions are, 37 inches long, 23 inches broad, and 24 inches deep; outside case ¼ inch; inside frame ⅛ inch; bound with ¾-inch straps of iron; can be taken to pieces at pleasure by removing six screw-bolts; will contain fifteen 32-pounder shot, placed on three wrought iron bars, 2¼ inches in diameter, not fixed. The chimney is 2 feet 6 inches high; the flue 14 inches by 6 inches, made in two pieces. The whole mounted on four cast iron trench-wheels, 18 inches in diameter. Rings are fixed to the bottom of the frame, to which drag-ropes may be attached, for the purpose of transporting the machine; the weight complete (but without shot and fuel) being about 720 lbs.

The following was the report of the committee:—

"Being charged with a quantity of shavings and light wood, ½ bushel of coals, and 2½ bushels of coke, the fire was lighted and allowed to burn twenty minutes; fifteen 32-pounder shot were then put in; in forty minutes they were serviceably hot, and in one hour and a quarter from the first lighting of the fire they were red-hot: these shot were removed, and fifteen fresh 32-pounders placed on the bars in the furnace: in twenty minutes these shot were red-hot; there was no fuel added. These last shot remained red-hot for four hours. It is therefore to be assumed, that in an hour and a quarter, with this furnace, you can have fifteen 32-pounder shot red-hot, and a succession of this number (fifteen) every twenty minutes afterwards, and by mending and adding to the fire, probably every quarter of an hour afterwards; and that they may be kept red-hot for a very long time, and remain so at inconsiderable trouble and expense.

"The fuel for charging the furnace for the trial described may be estimated at two shillings. It was found an improvement to add 6 inches to the height of the chimney, and to make it 3 feet in the last trial. The bottom of the furnace (or grate) was altered to seventeen ½-inch wrought iron bars, placed diagonally."

FUZE.—(*See* 'GRENADE' *and* 'PYROTECHNY.')

FUZE FOR MINES.—That in most general use is powder hose, which is made of strips of strong linen or calico, sewn together, and filled with powder; these when full vary from ½ an inch to an inch in diameter. The hose is attached to the charge, and laid in casing tubes to secure it from damage in tamping: these tubes are made from two pieces of wood, with a groove about 1½ inch wide and ¾ inch deep cut in each, one being placed upon the other, and fastened to it with wooden pegs as soon as the hose has been inserted between them.

To the end of the hose furthest from the charge, a piece of portfire, about 4 inches in length, is attached, and moist clay is kneaded round this, leaving the end alone free, thus preventing the possibility of the hose igniting until the portfire be burnt out, which affords ample time for the Officer who fires to escape.

A very good substitute for powder hose is Bickford's fuze, which is a tube of powder sewn round with tarred twine, and the outside covered over with pitch. This requires no casing, as from its construction it is not liable to be damaged by the tamping, and it is fired without any portfire being attached to it. It burns at the rate of 12 feet in five minutes, and when once lit cannot be extinguished even by water. It is procured from the maker in coils, having the appearance of thin rope.

E. C. de M.

G.

GABIONS.*—The dimensions of the gabions to be shown in the regulations of the depôt; the smallest admissible size being the sap gabion, 20 inches exterior diameter, and 2 feet 9 inches high, weighing from 25 to 30 lbs., as taught at Chatham. There will be also Battery Gabions, and Stuffed Gabions or Sap Rollers.

A proportion of the party will select the stakes from the materials brought into the depôt; they must be as straight as can be obtained, and something longer than the intended final dimension. A few men (carpenters, if they can be spared) will be employed as a squad in pointing one end; after which, another small party will saw off the other end to the exact length. The next squad will strike circles of the given diameter on the ground, and fix the stakes ready for wattling, keeping them to the required height by a gauge-stick: by this means the heads and points of the stakes will be level, and the whole will stand firm. The remaining men, in squads of three, wattle and finish the gabion: great expedition is gained by this division of labour. The party to supply ten squads actually wattling gabions, will be about thus:

Selecting stuff	3 to 6
Pointing pickets	3
Trimming do. to lengths	3
Fixing do. in circles	3
Wattling, in 10 squads	30
	From 42 to 45 men, or half

as many again as those employed in wattling.

The non-commissioned Officers will be distributed amongst the parties, especially with those who are sent to select the stuff.

Fir-wood gives the best stakes, being light and straight; large stakes may be split, as it is not essential that they should be round: dry wood, when it can be procured, is better than green for this part of the work. Willow, and all kinds of pliant green wood of sufficient thickness, is proper for wattling. The green dwarf oak will answer, but not well. The rods should be strong, both ends brought inside, and the web well hammered down with a hand mallet as the work goes on. When the rods are too thick, they may be split in two, but the bark must be kept outside. If the leaves are left on, it will make the gabion loose and feeble, but this requires vigilance, as stripping takes time and gives trouble. The small twigs which can be laid smoothly may be allowed to remain, as they give strength.

When finished, the gabion is to be raised out of the ground bodily by a stick thrust under the wattling. The upper and lower few rows must be bound up at unequal depths with slender twigs, or spun yarn, at three or four points on the circumference.†

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* From Notes of General Sir J. Burgoyne, Bart.

† The rods or twigs for binding should be of very pliable wood, twisted so as to separate the fibres and give toughness. The butt or large end is placed under the left foot, while the rod is twisted from left to right, gradually going downwards from the thin end, the rod being then called a *gad*, or *withe*. Two gads of large size should be paired round each end of the gabion, before the tying, to keep all firm.—Ed.

The party may be tasked at from 1 to 4 sap gabions per man per day, and paid for extra work besides. They will require hand-saws and bill-hooks. The Portuguese soldiers would each make four gabions 2 feet in diameter by 2 feet 6 inches in height per day; stuff very good, and delivered. They were paid 4*d.* for each gabion.

When the web of a gabion is made by a single rod being worked round, it is called *randing:* this requires an odd number of stakes. When a flat band of three or four rods is worked in the same manner, it is called *slueing:* this is common in basket-work. When two rods are used, crossing each other, it is called *pairing:* working with more rods than two, is denominated *waling*, and will now be detailed, as being the best.

Figs. 1, 2, show this process as effected by three only; but four, or even five, may be used conveniently. All that is to be observed is that each rod is successively twisted over and outside those before it, passing as many pickets or stakes (before being brought inside) as there are rods to be waled. As soon as a rod has passed behind one stake, it should be brought out again, or the work will be more polygonal than circular, especially in small gabions.

Fig. 1.

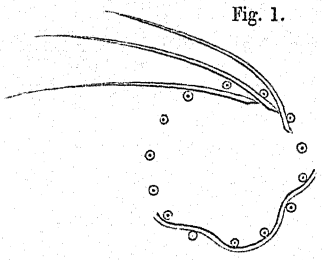
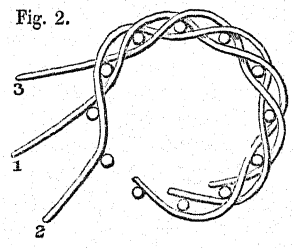


Fig. 2.



During and since the late war in the Crimea, iron gabions of various patterns have been employed. The most important of these are Captain Tyler's, 'The Sevastopol,' and Sergeant-Major John Jones's; which are described, as follows, in the Report of the Chatham Establishment.

ON IRON GABIONS.*

1. Capt. Tyler's Gabion.

This pattern is composed of a single sheet of galvanized iron of the length of the proposed gabion's circumference (6′ 2″), joined at the edges by thin pieces of wire passing through holes made for the purpose (figs. 3, 4). It has the following great advantages over the ordinary brushwood gabions, viz. small weight, portability, durability, and the short time required for putting it together: while its disadvantages are,—first, the great noise made by it when carried, or in being filled, which totally unfits it for Flying Sap, or any other secret operation; the difficulty in moving it with sap forks in sapping; its want of stiffness when put together, which prevents it keeping its shape when subjected to a slight pressure; and its want of hold of the ground, which makes it more liable than the ordinary brushwood gabion to be overturned in being filled.

Advantages.

Disadvantages.

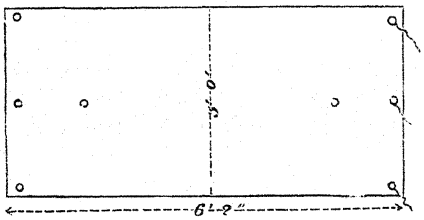
Result.

It is considered to be well adapted to resist the explosion of heavy guns in embra-

* Extracted from Report by Lieutenant George Philips, R.E., to the Director at Chatham.

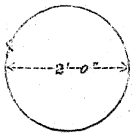
sures, and also for the revetments of batteries and fieldworks likely to be required to stand for a long time; but unfit for the revetment of trenches formed by any kind of sap.

Fig. 3.



PLAN OF SHEET OPENED.

Fig. 4.



PLAN OF GABION.

2. Sevastopol Gabion.

This is formed of 1¼-inch hoop iron, randed or waled, in single pieces at a time on the wooden pickets, which are 13 in number to the round (fig. 5), and 12 to the square gabion (fig. 6), about 200 feet run of hoop iron being consumed in each gabion.

Advantages.

The advantages of this kind of Gabion are, that it is very strong, particularly in the round form; it is made in a shorter time than the ordinary wooden one; it can be taken to pieces and packed; and the materials for making it are nearly always found with an army in the field.

Disadvantages.

Its great weight is its only apparent objection, but an important one. It is also expensive where, as in England, the materials have to be bought on purpose; but that objection does not apply on service.

Fig. 5.

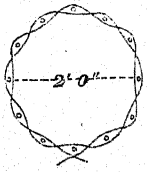
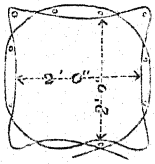


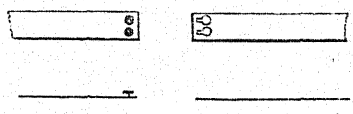
Fig. 6.



3. Sergt.-Major John Jones's Gabion.

This is formed by bands of thin sheet iron, 3¾ inches wide, on wooden pickets 12 in number, and 1½" by ½". Each band is composed of a single strip of sheet iron of the length of the circumference of the gabion, the ends being fastened together by 2 buttons at one end fitting into 2 slots at the other, as sketched (fig. 7). This gabion is made by putting one band together, laying it on the ground, and driving the pickets round it in their proper places, alternately inside and out; then placing successive rings on top of the pickets, and pressing them down on those already fixed, till the required height is obtained, taking care that each band is outside of those pickets of which the preceding one was inside, and *vice versâ*. Two men can make up such a gabion in 5 minutes. Two holes are made in each band for the insertion of carrying pickets.

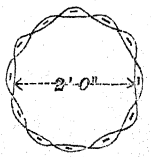
Fig. 7.



antages. The advantages of this gabion are very great, for it is extremely light, very cheap, easily and quickly made and unmade, very portable, easily repaired by substituting new bands or pickets for damaged ones, and very rigid when finished.

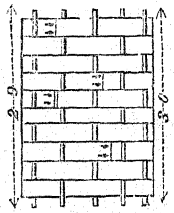
ults. These are considered to combine the advantages of all other iron gabions, *without their disadvantages;* for they do not make a noise when carried, nor alter their shape when being filled or afterwards; and appear by far the most serviceable gabions yet introduced. They are recommended to be made of galvanized iron, and with pickets $\frac{3}{4}$-inch thick, instead of $\frac{1}{2}$-inch, to give increased rigidity when put together.

Fig. 8.



PLAN.

Fig. 9.



ELEVATION.

COMPARISON OF GABIONS.

Nature.	Pattern.	Dimension of Base.	Height.	Weight in lbs. (empty.)	Weight in cwt. (filled.)	Time in making.	Number of men required.	Cost.	Comparative Durability.
								s. *d.*	
Wood	Common (round)	2′ 0″ diam.	2′ 9″	60* 40†	$5\frac{1}{2}$ $5\frac{1}{4}$	3 hrs. 3 hrs.	3 3	4 11 6 2	1
Iron	Capt. Tyler's (round)	2′ 0″ diam.	3′ 0″	26	$5\frac{7}{8}$	10 min.	2	4 10 galv. 8 11	5
,,	Sevastopol (round)	2′ 0″ diam.	2′ 9″	53	$5\frac{1}{2}$	$1\frac{1}{2}$ hrs.	3	9 0‡	5
,,	Do. (square)	2′ 0″ × 2′ 0″	2′ 9″	59	$5\frac{7}{8}$	$1\frac{1}{2}$ hrs.	3	10 $1\frac{1}{2}$‡	4
,,	Sergt.-Major John Jones's (round)	2′ 0″§ diam.	2′ 9″	26	$6\frac{1}{8}$	5 min.	2	3 0	5

There are other patterns, but all having so many objectionable points as to render it unnecessary to notice them.

STUFFED GABIONS, OR SAP ROLLERS.

"Finding by experiment that a large gabion, 4 feet in diameter, if stuffed with

* Green wood. † Dry wood.
‡ These would not be so expensive on service.
§ 20″ gauge.

small brushwood, was not musket-proof, but it filled with pickets, perfectly unmanageable, the sap roller was adopted by us at Chatham in preference."*

The sap roller is a hollow cylinder, formed by making two concentric gabions, each 6 feet long, one 4 feet in diameter, but the other not exceeding 2 feet 6 inches, so as to leave an interval of 8 inches all round between these two, which is stuffed with pickets of hard wood, not less than 1 inch thick at the tip. If willow be used, the diameter of the smaller gabion must be diminished some inches, in order that more pickets may be introduced.

The pickets and rods of which these gabions are made, must be much thicker than those of the sap gabions before described, the pickets being usually of deal, about $1'' \times 1\frac{1}{2}''$ square, as the object is strength, not lightness. The rods of the web are paired in forming the body of each gabion; 20 pickets are used for the larger, and 14 for the smaller gabion; the cylindrical form being retained by driving three pairs of strong pickets through the outer, and two pairs through the inner gabion, the pickets of each pair being at right angles to one another, and cut flush with the exterior of the web.

The large one requires 9 hours in making, small, 6 hours, and stuffing, 2 hours; and the finished roller weighs about $6\frac{1}{2}$ cwt. when a little dry.

GALVANISM.†—(*See also* 'VOLTAIC ELECTRICITY.')—Towards the close of the eighteenth century, Galvani made the observation that violent muscular contractions could be produced in the leg of a dead frog by touching the crural nerve with one end of a strip of zinc, the other end of which was placed in contact with a strip of copper touching the surface of the thigh; the contractions were not perceived unless the two metals were brought in contact: since no reason could be assigned for this effect by reference to known forces, the existence of a new form of force was assumed; this force received the name of *Galvanism*, and its action was spoken of as *Galvanic action*.

Somewhat later, Volta made some experiments with the view of extending and elucidating Galvani's observation, from which experiments he was led to infer that the muscular contraction was produced by a particular variety of electric force, to which he gave the name of *Voltaic electricity*. His fundamental observation was, that when two dissimilar metals are brought in contact with each other, and immediately separated, the one is found to possess those properties which belong to a metal charged with positive electricity, while the other has become negatively electrified (see *Electricity*). On referring to the chemical properties of the different metals, it was seen that the metal which exhibited the greatest readiness to combine with oxygen always became positive, the least oxidizable metal being negative. Thus, when potassium was brought in contact with zinc, the former became positive, the latter negative; but zinc assumed the positive state when brought in contact with copper, which has less affinity for oxygen; and copper could be made positive by opposing it to silver.

This phenomenon, like the development of common electricity by friction, has been explained by different philosophers upon one of the following assumptions: the first is to the effect that a certain *electric fluid* is associated with the particles of all metals, and that when two metals are brought in contact, the total amount of this

* From Lieutenant-General Sir C. Pasley's Instructions.

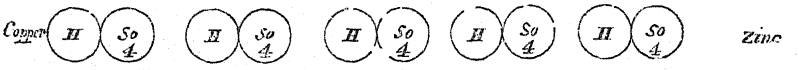
† By C. L. Bloxam, Esq., Lecturer at R. M. A.

fluid is unequally divided between them, the one acquiring a larger or *plus* + share becoming positively electrified, while the other is *minus* −, or negatively electrified. It is from this assumption that the symbols + and − for the two electric states have been conventionally adopted. The second assumption, which appears at least to possess the advantage of permitting the use of a more intelligible phraseology, supposes the compound nature of the electric fluid, and its decomposition when contact between the metals takes place, a portion of the positive fluid accumulating upon the one, while the other acquires an equivalent charge of the negative kind.

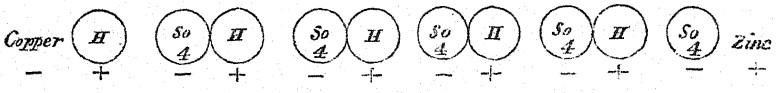
The disturbance of the electric equilibrium, however, becomes much more manifest, *i. e.* the amount of the *charge* which each metal receives becomes much greater, when the two metals are immersed in a liquid which is either incapable of acting chemically upon one of the metals, or which acts upon one much less powerfully than upon the other. This condition is fulfilled when, for example, plates of copper and zinc are immersed in diluted sulphuric acid, which acts only upon the latter metal; its associated electricity being decomposed, the positive charge accumulating upon those portions of the metal which are in immediate contact with the acid, while the remoter parts become negatively electrified, a disturbance which appears to be due to the chemical action of the acid upon the metal. Sulphuric acid may be represented by the formula $H\,SO_4$ (H = hydrogen, S = sulphur, O_4 = 4 atoms oxygen); the zinc having, under the conditions of the experiment, a greater chemical attraction for the SO_4 than the hydrogen has, will combine with the SO_4, forming the salt known as sulphate of zinc ($Zn\,SO_4$), which is dissolved by the water, while the hydrogen gas attaches itself in bubbles to the surface of the metal, thus preventing, in great measure, any further contact with the acid; in consequence of which, after the first few moments, the chemical action is very feeble, or might even, in extreme cases, be altogether arrested ($Zn + H\,SO_4 = Zn\,SO_4 + H$).

If a plate of copper be immersed in the acid, opposite to the zinc, it will not affect the result; but if the two metals be allowed to touch at any point, a very important change will pass over the features of the experiment, for it will now seem as if the acid were acting upon the copper, since bubbles of gas will be seen to form upon and escape from the surface of that metal, while little or no gas makes its appearance upon the zinc, though this is dissolved much more rapidly than before. A very ingenious account of this result has been given, affording an explanation which, if it does not quite convince the mind, has at least the merit of rendering very great service in all speculations concerning voltaic action. It is said that the particles of the acid intervening between the plates become *polarized, i. e.* acquire equal and opposite charges of electricity, the particles of H becoming +, and those of SO_4 −; the plate of copper also becomes negative, receiving a charge of negative electricity from the zinc, to which it imparts in return a charge of positive electricity. Now since bodies which are in dissimilar electric conditions attract each other, the negative plate of copper will attract the positive particle of H immediately contiguous to it, while the SO_4, being left with a charge of negative electricity, will abstract the H from the adjoining particle of $H\,SO_4$, leaving the SO_4 thus separated to rob another particle of acid of its H. Such a series of changes will proceed until the particle of $H\,SO_4$ in immediate contiguity to the zinc plate is decomposed, when the liberated SO_4 (−) will combine with the + zinc to form the sulphate. A clearer conception will be formed of the manner in which this action is propagated along the chain of particles of acid intervening between the copper and zinc, when it is remembered that the decomposing action sets off at once from each end of the chain towards the centre, and that a divellent action must thus be simultaneously exerted upon the whole chain.

Condition of the intervening particles of acid before the contact of the copper and zinc:—



During the contact:—



We may then regard the action as dependent upon the tendency of the opposite electricities to recombine with and neutralize each other, the negative electricity of the copper plate being always in process of neutralization by the positive electricity which it receives from the particles of hydrogen, while the positive charge of the zinc is being neutralized by the negative particles of SO_4. The effect then is the same as if an actual *current* of positive electricity were continually passing from the zinc through the liquid to the copper, and conversely, as if a current of negative electricity were passing from the copper through the liquid to the zinc; and it is this kind of *transmission by polarization* which is always implied when it is said that a current of voltaic electricity traverses a liquid: this is often spoken of as *convection* of voltaic electricity. And the current is now said to *circulate*, since there is, as above mentioned, a continual exchange of electricities between the copper and zinc at the points of contact; so that a fair idea of the result is imparted by saying that a positive current is passing from the zinc through the liquid to the copper, and back from the copper through the points of contact between the metals to the zinc, while a negative current passes in the opposite direction, viz. from the copper through the liquid to the zinc, and back through the points of contact to the copper. Such language, though it very much assists the memory by bringing these phenomena into comparison with ordinary mechanical effects, must be employed with great caution, lest it should lead to the adoption of erroneous ideas respecting the true nature of the change, which is obviously *sui generis*, and quite distinct from any principles of mechanism.

It will be obvious that a current cannot be made to circulate unless the exciting liquid in which the metals are immersed be a compound substance, since an elementary body would not allow the requisite polarization of its particles.

The arrangement through which a current is circulating is generally spoken of as a *closed circuit*.

The amount of disturbance of the electric equilibrium, commonly spoken of as the *electromotive force*, is dependent upon the nature of the metals and of the exciting liquid employed, and is greatest, *cæteris paribus*, when that liquid is selected which has the most powerful chemical action upon one of the metals and has no action upon the other.

The greater the difference between the affinity of one of the constituents of the exciting liquid for one of the metals employed, and its affinity for the other metal, the greater will be the electro-motive energy of the arrangement.

In all cases, the direction of the current (by which expression that of the positive current is generally implied) will be determined on the same principles as have been explained in the case of copper and zinc in diluted sulphuric acid, the positive current always passing from the metal acted upon, through the liquid, to the metal which

is not attacked, and returning through the metallic points of contact to the active metal.

It is not necessary that the metals immersed in the exciting liquid be placed in immediate contact with each other, for a current is found to circulate if they are connected by means of any conductor, such as a metallic wire, and it then becomes much easier to recognize the existence of electric disturbance, for the wire will be found to rise in temperature when the plates are immersed in the acid; it will also have acquired magnetic properties, and will cause a magnetic needle, freely suspended above it, to assume a position at right angles to the conducting wire. If the conducting wire be divided, a bright minute spark will be seen when the two ends are brought together; and if a binary chemical compound be interposed between the ends of the two wires, it will, in many cases, be decomposed into its constituents, each constituent being invariably separated at the end of the same wire. The ends of the wires, in such a case, are commonly spoken of as the *poles* of the battery, the *positive pole* being the end of the wire attached to the *copper* plate, or to a plate of another metal playing the part of a copper plate, while the *negative pole* is attached to the *zinc* plate, or to its representative. The term *electrode* is sometimes substituted for pole. The *positive* pole is termed by Daniell the *zincode*, and by Faraday the *anode;* while the same writers respectively have termed the *negative* pole, *platinode* and *cathode*.

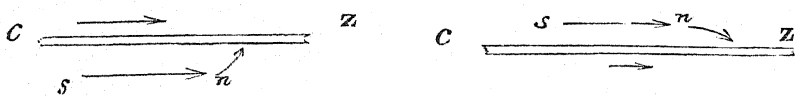
The degree in which either of the above manifestations (*i. e.* of heat, magnetism, or chemical decomposition) is exhibited by the wire, may serve, with certain limitations, as a measure of the amount of electric disturbance which has taken place; but the amount of chemical decomposition which the current is capable of effecting in a given time, is the only sure measure of the actual amount of voltaic force in circulation. The *Voltameter* of Faraday is constructed upon this principle, and consists of an apparatus in which water acidulated with sulphuric acid may be decomposed by the current, in such a manner that the gases (Oxygen and Hydrogen) into which the water is resolved may be collected and measured: the amount of these gases affords a measure of the force of the current. (See *Electricity*, Plate XII. fig. 3.)

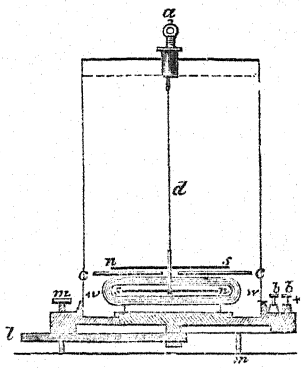
The development of heat is taken advantage of to measure the electric disturbance in the *Intensity Galvanometer*, recently described by Capt. Ward, R.E., which will be again referred to.

In the ordinary *Galvanometer*, the power of the current to deflect a magnetic needle is turned to account, the needle being freely suspended by a fibre of silk within a flattened coil of wire, through which the current is made to circulate, the amount of deflection of the needle being measured by a graduated arc. The sensitiveness of the instrument is much increased by rendering the needle *astatic, i. e.* independent of the directive powers of the earth's magnetism, which may be effected by suspending another needle parallel to it and at some distance above it, with its poles reversed. The use of the coil of wire is to render a feeble current capable of acting upon the needle, by accumulating its action; since it is found that, as would be expected, the needle is deflected in the same direction by a current passing under it from right to left, or over it in the opposite direction.

The galvanometer indicates not only the amount of a current, but also the direction in which it is passing, for the direction in which the deflection of the needle takes place depends upon that of the current. When the wire is placed in the magnetic meridian, with the end connected with the zinc plate towards the north, and the needle is placed below the wire, the N. pole will deviate westward; if the needle be placed above the wire, the deviation is eastward; and by reversing the direction of the current, these effects would also be reversed. It appears then that when the

positive current is flowing along the wire towards the north, the wire being above the needle, the N. pole will deviate westward.





The annexed figure represents a section of the astatic galvanometer enclosed in a glass case. *ns* and *sn*, the astatic needles, suspended by the fibre of silk, *d*. *a*, a screw for lowering the needles when not in use, so as to take the strain off the silk fibre; *cc*, a sheet of copper, with a graduated arc for measuring the deviation of the needles; *bb*, binding screws to receive the wires carrying the current; *l*, a lever for placing the coil, *w*, parallel with the needles; *mm*, levelling screws.

There are many circumstances influencing the power of a galvanic arrangement, which have to be taken into account in any practical application of this remarkable variety of force. These may be illustrated by reference to the simple example of zinc and copper in diluted sulphuric acid, in order that they may be subsequently applied in more complicated cases.

(*Ohm's Law.*) The *available force* to be derived from any voltaic arrangment *varies directly* as the *electro-motive force*, and *inversely* as the *sum* of all the *resistances* opposed to the passage of the current. Thus, if F represent the available power, E the electromotive force, and R the sum of the resistances, $F = \frac{E}{R}$.

It has been already stated that the value of E depends solely upon the nature of the metals and of the exciting liquid, and it would therefore be expected to be as constant as the chemical relations of these substances. In practice however it is found to vary with the purity of the zinc, and, although the supply of acid be kept up, with the length of time for which the zinc and copper plates have been in use.

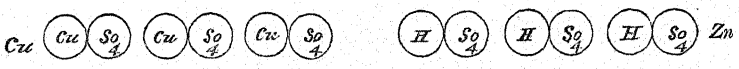
The sheet zinc of commerce is not perfectly homogeneous; minute particles of carbon, of lead, and other impurities may be found disseminated through it, and when the plate is plunged into diluted acid, these impurities set up little voltaic currents which interfere with and lessen the force of the greater action; this is known as *local action*, and gives rise to a great waste of the zinc, even when the voltaic circuit is not completed. If the surface of the zinc, after being cleansed by immersion in the acid, be rubbed over with mercury, or *amalgamated*, the plate will not be acted upon by the acid until the circuit is completed, for its surface is protected by a compound of mercury with zinc which has been formed upon it.

The bubbles of hydrogen which attach themselves to the plate of copper, are also apt to give rise to a counter-current, which diminishes the force of the main current. This source of irregularity in the action has been remedied in the *constant* voltaic arrangement of Daniell,* by saturating the acid liquid with sulphate of copper ($Cu\,SO_4$), which is decomposed by the hydrogen, the latter taking the place of the

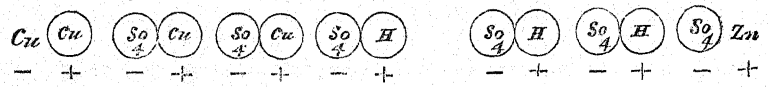
* For detailed descriptions of this and other batteries, see the Article on ELECTRICITY.

copper in the combination, and producing sulphuric acid ($H\,SO_4$), while the metal is deposited upon the surface of the copper plate; but if the zinc were allowed to come into actual contact with the solution of sulphate of copper, since the affinity of the zinc for SO_4 is greater than that of the copper, this metal would be displaced by the zinc, and a coating of metallic copper would be deposited upon the surface of the zinc plate, and all voltaic action would be suspended. To avoid this, the zinc is immersed in diluted sulphuric acid alone, which is separated from the solution of sulphate of copper by a porous membrane or a partition of unglazed earthenware, which becomes thoroughly wetted with the acid, and allows the polarization of the particles to take place through it, without permitting any actual mixture of the two solutions. The following diagram represents the mode in which the action is propagated in such an arrangement, the dividing space representing the porous partition:—

Before closing the circuit:—



After closing the circuit:—



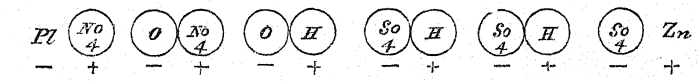
In Smee's arrangement, a silver plate coated with platinum is substituted for the copper plate; the hydrogen is found to detach itself far more readily from such a surface than from the smoother surface of the copper plate.

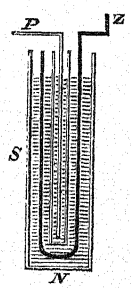
In Grove's voltaic combination, platinum is employed instead of copper, and is immersed in concentrated nitric acid placed in a flat porous cell, in order to keep it separate from the diluted sulphuric acid which is in contact with the zinc; in this case, the hydrogen is absorbed by the nitric acid ($NO_4\,O$) and converted into water by a portion of its oxygen, while the peroxide of nitrogen (NO_4) thus liberated remains undissolved in the undecomposed nitric acid.

Before closing the circuit:—



After closing the circuit:—





The parts of a Grove's cell are shown in the figure. *P*, the platinum plate, placed in the porous cell *N*, containing nitric acid. *Z*, the zinc plate, bent to lap round the porous cell; this should be freshly amalgamated from time to time. *S*, the vessel containing the dilute sulphuric acid.

Bunsen has contrived an arrangement upon the same principle, in which however a dense variety of coke is employed instead of platinum.

The resistance offered to the passage of a current, in any arrangement, may be divided into that which is opposed by the liquid in the cell itself, and that due to the wire or other con-

ductor through which the current has to pass. The amount of the resistance (L) opposed by the liquid, varies directly as its specific resistance (S), and as the thickness (T) of the layer of liquid intervening between the two plates; while it varies inversely as the sectional area of this layer, *i. e.* as the mean superficial area (A) of each plate.

$$L = \frac{ST}{A}$$

The specific resistance of any liquid depends, of course, upon its conducting power, which varies greatly for different liquids. A saturated solution of sulphate of copper conducts 400 times as well as water, and moderately strong nitric acid conducts 18 times as well as the solution of sulphate of copper: these facts are turned to advantage in the voltaic arrangements of Grove and Daniell. How much more worthy of consideration is the resistance of the liquid than that of the wire, may be learnt from the fact, that the conducting power of nitric acid is to that of platinum in the ratio of about 1 to 80,000, and to that of silver as 1 to 1,000,000. The specific resistance of liquids diminishes as the temperature rises, and the action of the voltaic arrangement is therefore favoured by warming the exciting liquid.

The equation given above indicates the advantage of diminishing the thickness of the layers of liquid intervening between the plates by bringing them as near together as possible, and of increasing the sectional area of the intervening liquid by enlarging the surfaces of the plates.

The resistance (w) of the conducting wire depends, like that of the liquid, upon its specific resistance (s), its length (l), and its sectional area (a); varying directly as the two first, and inversely as the last, so that $w = \frac{sl}{a}$

Different metals have different conducting powers, and therefore offer different resistances to the passage of the current: the conducting powers of the metals in ordinary use have been stated by Becquerel, junior, to stand as in the following table:—

	At 32° F.	At 212° F.
Silver	100	71·316
Copper	91·517	64·919
Gold	64·960	48·489
Zinc	24·063	17·596
Tin	14·014	8·657
Iron	12·350	8·387
Lead	8·277	5·761
Platinum	7·933	6·688
Mercury	1·738	1·575

Copper wire therefore is, practically, the best medium for the transmission of voltaic force; and it should be noticed that the resistance is materially diminished by lowering the temperature of the wire as far as possible.

It is obvious that as short a wire as possible should be employed in voltaic operations, and that this should have as great a weight per yard as may be convenient.

The voltaic manifestation of a single pair of metals is not nearly so energetic as that obtained when a number of similar pairs are arranged side by side in such a manner that the copper or platinum plate of one pair is connected, by means of a strip or thick wire of copper, with the zinc plate of the next pair, the last platinum plate at the one end of the series being connected with the last zinc plate at the other by the wire conveying the current. Such an arrangement is termed a *voltaic battery*, and is the form generally employed for experimental purposes.

The *actual* amount or *quantity of force* which circulates in a battery of this description is no greater than that which would be obtained from a single pair of plates, for although six times the power is generated by the consumption of six times the quantity of zinc in a given time, the additional amount of force is expended in overcoming the additional resistance of the five layers of liquid contained in the five cells.

This important fact can readily be exhibited in a general form by reference to the equation $F = \frac{E}{R}$, and so modifying it as to substitute for R (sum of the resistances) the resistance of the liquid in each cell (= L), supposing the terminal plates of the battery to be connected by a short thick wire, so that the value of w (the resistance external to the battery) would be insignificant; then $\frac{E}{L} = F$ would represent the amount of force in circulation in one cell, and if n such cells be taken, $\frac{nE}{nL} = F$ would still exhibit the result.

But although the *quantity* of the force cannot be increased in this way, its *intensity*, or power of overcoming resistances external to the battery, is very considerably enhanced, as will be rendered evident by substituting $L + w$ for R in the equation $F = \frac{E}{R}$. For, if $F = \frac{E}{L + w}$, it will also $= \frac{nE}{nl + nw}$; that is, the resistance w, external to the battery, may, if n cells be employed, be multiplied by n without affecting the force of the current.

The conclusion, of high practical importance, drawn from this is, that wherever great resistances external to the battery have to be overcome,—when, for example, the current is to be sent through a great length of wire, as in telegraphy and military engineering,—intensity is of more importance than quantity, and more is gained, after certain limits have been passed, by adding to the number of cells than by increasing the size of the plates.*

Under the guidance of the very simple principles which have been laid down, there is no difficulty in increasing the power of the battery to any extent which may be found necessary in practice. On inspecting the equation $F = \frac{E}{L + w}$, it is evident that F may be increased by diminishing L or w, or both. L (the resistance of the liquid) may be diminished by increasing the superficial area of the plates, or by diminishing the distance between them: suppose L to have been reduced to $\frac{1}{n}$th, the force in circulation will be represented by $\frac{E}{\frac{L}{n} + w} = \frac{nE}{L + nw} = F'$.

w may be virtually diminished by increasing the number of cells, for supposing these to be multiplied by n, the circulating force will be expressed by—

$$\frac{nE}{nL + w} = \frac{E}{L + \frac{w}{n}} = F''.$$

Which of the two methods will be attended with the greatest advantage, that is, whether F′ or F″ will be the greater, will depend upon the question whether L or w is the greater. If then the resistance of the liquid be greater than that of the wire,

* The Author has to acknowledge the great assistance which he has here derived from Captain Ward's Paper, upon the Application of the Voltaic Battery to Military Purposes.

it is more advantageous to increase the size of the plates; but if the resistance of the wire be the greater, the number of cells must be increased. Theoretically, the most economical battery would be that in which L and w were precisely equal; but in practice it is found that better results are obtained, on the whole, when w somewhat exceeds L.

In any practical application of the voltaic battery, it becomes a matter of importance to be able to determine the values of the different factors in the equation $F = \frac{E}{L + w}$; and this may be effected with the assistance of a galvanometer, and of Wheatstone's *rheostat* and *resistance coils*. This is an instrument by which measured amounts of resistance may be introduced into the voltaic circuit; if the effect of such resistance upon the amount of the current in circulation be measured, the comparative values of E, L, and w, in different arrangements, may be deduced from it.

The rheostat consists of two equal cylinders 6 inches in length and 1½ in diameter, placed side by side and parallel to each other. One of these cylinders is made of well baked wood, and the other of brass; the former is traversed by a spiral groove, the thread of which contains 40 turns to the inch, so that the coils of a wire wound upon this cylinder would be perfectly insulated from each other, since dry wood does not allow the current to pass along it. A wire wound upon the second (brass) cylinder, however, would not be insulated, and the current would pass at once along the cylinder without traversing the wire. Each of these cylinders is capable of being turned upon its axis for the purpose of reeling the wire off one cylinder on to the other, and the length of wire upon the wooden cylinder may be read off by a graduated scale. The instrument may be introduced into any circuit by means of binding screws, which are in metallic connection with two brass springs, one of which presses against the end of the brass cylinder, and the other against a ring of brass fixed upon the end of the wooden cylinder, and serving to transmit the current to the wire coiled upon it.

The arrangement of the rheostat and resistance coils is shown in Miller's 'Elements of Chemistry,' p. 356. In the woodcut, fig. 187 of that work, g and h represent the cylinders of wood and brass respectively upon which the wire is coiled, g being provided with a dial on which the fractions of a turn may be read off; B is a delicate galvanometer, with a microscope for reading off the graduations; C, the voltaic arrangement to be tested; and D, the resistance coils; the arrows indicate the direction of the (positive) current.

Suppose it is required to determine the relative value of E for any two voltaic arrangements, where L is constant. The first arrangement is connected by one of its wires with a galvanometer, and by the other with the rheostat; a wire passes from the other binding screw of the rheostat to the galvanometer, so that both these are made parts of the circuit. The resistance offered by the wire upon the wooden cylinder is then increased or diminished by coiling or uncoiling it, so as to bring the galvanometer needle to 45°; the wire is then uncoiled and the number of turns counted which are required to bring the needle to 40°. This number of turns of the wire may be taken to represent the value of E in the experiment. If the second voltaic arrangement be now substituted, and the number of turns required to effect the same object be counted, we shall obtain the relative values of E in the two cases.

The resistance coils are simply measured coils of wire, insulated by covering them with silk, which may be introduced into the circuit when a greater amount of resistance is required than can be introduced by the rheostat.

The most important cases in which voltaic electricity has been usefully employed

are: 1, the production of light; 2, the explosion of gunpowder; 3, the electric telegraph; and 4, the deposition of metals, or electrotype.

ELECTRIC LIGHT.

The heat developed by the passage of a current through any conductor, is dependent upon the resistance which such conductor opposes to its passage; *cæteris paribus* then, the worse the conductor, the higher the temperature to which the current gives rise. If the wires of a powerful battery be terminated by small pencils of the dense cake from the gas-retorts, which will offer considerable resistance to the passage of the current, it will be found that when the points of these pencils are brought together, a brilliant star of light is produced; and if the points be then separated again, an arc of brilliant white light will continue to pass between them, the length of which varies with the power of the battery. The air, like other gases, has, under ordinary circumstances, scarcely any power of conducting voltaic electricity; but when very highly heated, as in this experiment, it allows it to pass more freely, though it exhibits even then sufficient resistance to cause the development of a most intense heat. But the heat alone would not account for the brilliant white light; this is explained by the transfer of solid particles from the positive to the negative pole, which is always found to occur when a spark passes between two conductors. The minute particles of carbon, being raised to so high a temperature, emit the brilliant light. The combustion of the carbon must not be supposed to affect this result; for not only is this variety of carbon one of the least combustible, but the light can be manifested in a globe exhausted of air. This transfer of the particles between the two points, is one of the most serious obstacles to the practical application of the light, since it causes the distance between them to vary perpetually, and produces a corresponding irregularity in the strength of the current. This has been overcome by Duboscq, who has arranged a small electro-magnet and a train of clockwork in such a manner that the force of the current itself adjusts the distance between the points; the light so obtained is now in very general use for optical experiments, and is spoken of as likely to be employed for signalling. Much doubt exists whether the light will ever be available for ordinary illumination, on account of the expense attendant upon its production; but it is much to be desired that some attempt should be made to employ it in *fiery* coal-mines, where it might be enclosed in a strong glass globe, and its light reflected along the galleries.

EXPLOSION OF POWDER BY VOLTAIC ELECTRICITY.*

This application depends upon the same principle as the preceding, viz. the development of heat in the passage of the current through an imperfect conductor, usually a very thin platinum wire.

The subject has recently been very carefully investigated by Captain E. W. Ward, R.E., whose treatise upon the Application of the Voltaic Battery to Military Purposes† should be carefully studied by all interested in the use of the battery in engineering operations.

For the purpose of directly testing the applicability of any particular form of battery to the explosion of powder, Captain Ward devised an *Intensity Galvanometer* (Plate II.), which was so constructed that any length of platinum wire of any thick-

* See also an Article upon this subject under ELECTRICITY.

† 'Professional Papers, R.E.,' New Series, vol. iv.

ness (or weight per yard) could be introduced into the circuit, and the standard force which was required to be put in circulation was taken as that necessary to just melt the wire.

By means of this instrument, combined with Wheatstone's rheostat, not only can the relative merits of the different batteries be put to the proof, but the length and thickness which it is desirable to give to the copper and platinum wires may also be ascertained. Moreover, by arranging several wires in the same apparatus, experiments may be made upon the best method of firing a number of charges simultaneously.

Captain Ward employed his galvanometer to determine the relative values of several batteries, with the following results:—

Grove's	(zinc, platinum, sulphuric and nitric acids) . .	410
M'Callan's	(zinc, iron, sulphuric and nitric acids)	410
Dalgleish	(zinc, platinum, nitric acid)	344
Daniell	(zinc, copper, sulphuric acid, sulphate of copper)	235
Smee	(zinc, platinized silver, sulphuric acid)	116

Although M'Callan's battery gave such good results, in point of power, there were several practical difficulties in its employment, which gained the preference for that of Grove.

In Dalgleish's very ingenious battery, the force is generated by the action of nitric acid, placed in cylindrical vessels of platinum, upon rods of zinc attached to a frame, and, by a simple contrivance, simultaneously lowered into the acid when the current is required. Captain Ward is inclined, for short circuits, and in cases where rough handling is not apprehended, to prefer this form of battery even to Grove's, but considers the latter decidedly better for field-service.

Under the guidance of the principles which have been above laid down for determining the value of any voltaic arrangement, a modification of Grove's battery was constructed, furnishing the maximum of power in the smallest compass. The zinc plates of this battery (Plate I.) measured 2″ × 1″, and the platinum plates 2″ × 2″, the former facing the latter on each side; these plates were joined by welding them together at their upper ends, the zinc being bent over for that purpose; one plate of each pair was placed in a separate cell, the platinum immersed in nitric acid being separated from the zinc of another couple immersed in dilute sulphuric acid by the porous cell containing it and the nitric acid. The distance between each pair of plates was little more than $\frac{5}{10}$ inch. Six pairs of such plates could be arranged in a box not exceeding 7″ × 4″ × 4″.

The nitric acid recommended for charging this battery is the common acid of commerce, of sp.gr. about 1375; it should be free from hydrochloric acid, lest it corrode the platinum. The common sulphuric acid, sp.gr. 1846, should be diluted with 8 parts of water.

The conducting wires should be made of copper, about $\frac{1}{10}$ inch in diameter (weighing 250 grains per yard), and covered with gutta percha, in order to insulate them. If the wire is to pass under water, the coating of gutta percha must have considerable thickness; but for explosions on land, expense may be saved by employing a more thinly coated wire.

If the explosion be made under water, or in very moist earth, only one wire is necessary, since the current will return to the battery through the water or earth, which atone for their inferior conducting power by their great sectional area. In this case, the opposite pole of the battery to that from which the long wire proceeds, should be connected by means of a short thick wire with a metal (copper) plate pre-

senting considerable surface, and buried in the moist earth or in the water. When two conducting wires are employed, they should be laid as far apart as possible.

For the bursting-charge, Captain Ward recommends a platinum wire $\frac{3}{8}$ inch in length, and weighing 1·65 grains per yard.

The following simple rule is given for firing a mine at any distance with the above battery in good work:—

Take the whole circuit in yards, including distance up and down shafts, add to it 100 yards for every charge in the circuit, and divide by 46 for the number of cells. As a practical rule however, allowing that the battery may not be in the best condition, $28\frac{1}{2}$ should be the divisor employed to ascertain the number of cells which must be introduced into the battery in order to effect the explosion.

THE ELECTRIC TELEGRAPH.*

The great principle involved in the application of voltaic electricity to telegraphic purposes has been brought prominently forward in the description of the ordinary galvanometer. Space will not allow us to do more in this paper than to illustrate the simplest mechanical arrangements by which this principle may be applied for making signals at a distance.

The battery usually employed for working the telegraph consists of alternate pairs of copper and amalgamated zinc plates, arranged in wooden troughs divided into compartments, containing sand moistened with diluted sulphuric acid.

The conducting wire is generally made of iron, about $\frac{1}{8}$ inch in diameter, and covered with zinc, to prevent it from rusting; this wire is insulated by supporting it in tubes of porcelain, which are attached to posts fixed at regular distances along the line. A return wire is not generally required, the circuit being completed by broad metallic plates buried in the earth. When the wire cannot be supported upon posts, a copper wire is usually employed, since its superior conducting power allows its diameter to be greatly diminished. In order to insulate the copper wires, they are coated with gutta-percha; and are then protected from injury by packing them in iron pipes, which are buried in the earth. For the submarine telegraph, several copper wires, coated with gutta-percha, are twisted round a rope, which is then covered with a flexible metallic coating by twisting several thick iron wires round it, giving it the appearance of a wire cable.

The instrument by which the signals are exhibited is constructed in the same manner as an ordinary astatic galvanometer, placed vertically instead of horizontally, and furnished with a dial plate on which the oscillations of the *front* needle (that which is not surrounded by the coil) may be noted. When the instrument is ready to receive a signal from a distant station, the galvanometer is in connection with the battery at the distant point, so that the current from that battery passes through the conducting wire, through the coil, deflects the needle, and returns by the earth to its starting-point. When it is desired to transmit a message to the distant station, a handle is turned, which acts upon a simple arrangement of metallic springs in such a manner as to break the connection with the distant battery, and to connect the instrument with the battery belonging to it; the current then passes through the coil of the galvanometer, deflects the needle, is transmitted along the wire through the coil of the distant galvanometer, where it produces a similar deviation in the needle, and returns through the earth. By turning the handle in the opposite direc-

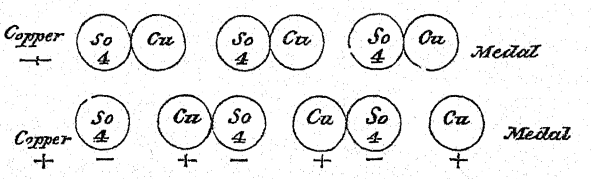
* Abridged from Miller's 'Elements of Chemistry,' Part I. For details respecting the construction of telegraphs, see VOLTAIC ELECTRICITY.

tion, the direction of the current through the coil is reversed, and therefore the needle is deflected in the opposite direction. Having thus at our disposal a method of regulating the vibrations of the needle, it only requires a little ingenuity to frame a code of signals from them. The lower ends of the needles are somewhat heavier than the upper, to cause them to return more readily to their former position.

ELECTROTYPE AND ELECTRO-PLATING.*

This very useful application of voltaic electricity depends upon its power of inducing chemical decomposition. This power, usually spoken of as *electrolysis*, does not extend over every chemical compound to the same degree; different compounds require very different degrees of force to decompose them, dependent, of course, upon the strength of the affinity (to use the language commonly adopted) which holds their constituents together. The chief laws to which electrolysis is subject are the following:—1, the *electrolyte*, or substance to be decomposed, must always be in the liquid state; this follows from the second law. 2, The constituents of the electrolyte are resolved into two groups, which are attracted to opposite poles of the battery; thus oxygen, chlorine, and the acids, are usually attracted to the positive pole, or pole in connection with the copper plate, while hydrogen, the metals, and the alkalies, pass to the negative pole, or that in connection with the zinc plate. These two groups into which the electrolyte is resolved, are termed by Faraday, *ions*; the *anion* being that which goes to the anode, or *positive* pole, and the *cathion* that which goes to the cathode, or *negative* pole. 3, The amount of decomposition effected by the battery in a given time depends upon the degree of action in the battery itself, and is directly proportionate to the quantity of electricity in circulation, that is, to the quantity of zinc dissolved. 4, Only those substances which are composed of a conductor and a non-conductor can be decomposed by the voltaic current; no compound of two conductors, or of two non-conductors, can be so decomposed.

The process of electrotype is employed for obtaining copper facsimiles of engraved plates, medals, &c. It consists in causing a deposit of metallic copper to take place upon the surface of the object to be copied; when this deposit is removed, it is found to present a faithful copy of the surface upon which its deposition took place. In order to effect the deposition of the copper, the object to be copied, which must be a conductor of electricity, or must be made so by brushing it over with plumbago, is attached by a conducting communication to the wire forming the negative pole of a battery of moderate power, and is then plunged into a saturated solution of the sulphate of copper, in which a copper plate connected with the positive pole of the battery is also immersed. The copper is gradually deposited from the solution upon the object to be copied, while an equivalent proportion of the copper plate is dissolved by the liquid, according to the following diagram.



In electro-plating a coherent deposit of silver or gold is deposited upon the surface

* A more extended account of this application of voltaic electricity will be found in the article on ELECTRICITY.

of the article to be plated, which is attached to the negative pole of the battery, and immersed in a solution of the cyanide of silver or gold in cyanide of potassium; the positive pole being connected with a plate of silver or gold immersed in the same solution. In this way the strength of the solution is kept constant, since the weight of metal dissolved from the positive pole is equal to that which is deposited upon the negative pole.

ELECTRO-MAGNETIC ACTION.

It has been already stated, that the wire through which the voltaic current is passing possesses magnetic properties. If some iron filings be brought in contact with the wire, they will adhere strongly to it, and will fall off again when the connection with the battery is broken; each iron filing becomes a magnet while the current is passing.

If the wire be coated with silk and be then coiled into a spiral, a bar of soft iron placed in the axis of this spiral becomes magnetic while the current is passing; and by bringing the end of the spiral back to its starting-point, and coiling a second spiral upon it with its threads in the same direction, an extraordinary power of inducing magnetism is attained. This fact is of great importance, as upon it every proposition for employing electricity as a motive force is founded.

The poles of the temporary magnet so produced are dependent upon the direction of the current. When a current passes through a right-handed helix, the end at which the current enters acquires the properties of a south pole, while that at which the current leaves the helix is a north pole; in a left-handed helix the effects are reversed. The poles of a temporary magnet placed in the axis of the helix will be similar to those of the helix itself.

INDUCED CURRENTS.

If a wire through which a voltaic current is passing be placed parallel to a second wire, the two ends of which are connected with a galvanometer, the latter will not be affected whilst the current is passing uninterruptedly through the first wire; but if this *primary* current be suddenly stopped by breaking the connection between the wire and the battery, a *secondary*, or induced, current will pass through the second wire in the same direction as that in the battery wire; this current, which is only of momentary duration, is said to be *direct*. When the first wire is again put in communication with the battery, another momentary current is induced in the secondary wire, but this current is *inverse*, that is, in a direction opposite to that of the primary current.

These currents may be rendered far more intense by coiling both wires into concentric helices, and placing the wire for the primary current in the axis of the coil intended to convey the secondary current.

MAGNETO-ELECTRIC ACTION.

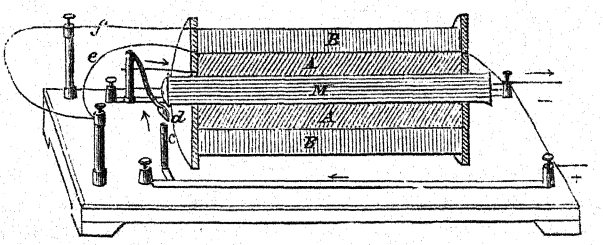
As Electricity is capable of inducing magnetism, so this latter may give rise to an electric current. If a bar-magnet be introduced into the axis of a helix of copper wire connected with a galvanometer, a momentary current will be indicated by the deflection of the needle; if the bar be allowed to remain in the helix, the needle will soon return to its former position, but, on withdrawing the bar, a current will again pass through the wire in an opposite direction to that of the first current. When the north pole of the magnet is introduced into a right-handed helix, the

(positive) current passes through the helix in the opposite direction to that of the magnet. If a bar of soft iron (unmagnetized) be placed in the helix, and temporary magnetism be induced in it by holding the opposite poles of two bar-magnets to its extremities, a current will also be induced in the wire.

If two concentric helices be arranged as in the experiment upon induced currents, and a bar of soft iron be placed in the axis of the primary coil, this bar, in acquiring and losing magnetism, will give rise to a secondary current corresponding in direction to that induced by the primary coil alone.

These secondary currents possess a very high degree of intensity, varying with the length of wire contained in the coil, and furnish very brilliant sparks; they have long been employed for communicating shocks in the medical application of voltaic electricity.

The most efficient form of apparatus for applying the secondary current is that known as *Ruhmkorff's coil.* It consists of two concentric helices of insulated copper wire, the primary or inner coil being shorter and stouter than the secondary or outer coil, which is about 4 or 5 miles in length; great care is taken to ensure the complete insulation of each coil of wire. A bundle of soft iron wires is placed in the axis of the primary coil, and one of the ends of this bundle projects beyond the coil over a little movable hammer of soft iron faced with platinum, which rests upon an anvil faced with the same metal. This hammer and anvil form parts of the circuit included within the wire of the primary coil, and when the current is passing through this wire, the bundle of soft iron, becoming a magnet, attracts the little hammer, raises it from the anvil, and arrests the passage of the current; the cessation of the current causes the iron to lose its magnetism, the hammer therefore falls back upon the anvil; the current again passes, and thus a very frequently interrupted current is maintained, developing a secondary current of great intensity. A most important feature in this coil is the *condenser*, as it is called, which consists of an extensive surface of oiled silk, coated on each side with tin-foil, but leaving a margin uncoated; this is folded up, to occupy less space, but so that the opposite coatings may not come in contact. Each of these coatings is provided with a conducting strip of metal, which is connected with the portions of the primary coil where the interruption is made, so that, when the current is broken, the interrupted ends are respectively in metallic communication with the opposite coatings of the condenser. The action of the condenser does not seem to be fully explained, but the arrangement of its coatings would suggest a similarity between its action and that of the Leyden jar.



The form given to the coil by Ruhmkorff is here shown. AA, the primary coil; *d*, the hammer; *c*, the anvil; M, the bundle of soft wires attracting the hammer, *d*, when magnetized by the current; BB, the secondary coil, the wires from which, *e*, *f*, are connected with the binding screws upon the heads of the insulating columns.

The signs + and − represent the wires from the battery. The condenser is not shown in the figure, being contained in a box on which the coil is supported.

Many very beautiful and interesting experiments can be performed with such a coil; but the chief useful application of it which has yet been proposed, is for the explosion of gunpowder in bursting charges. When the coil is used for this purpose, the thin platinum wire may be dispensed with, the ignition of the powder being effected by the spark passing between the wires of the secondary coil, which are for this purpose brought pretty near to each other. Three or four cells of Grove's battery are generally sufficient to effect the ignition of powder when this coil is employed.

MAGNETO-ELECTRIC MACHINES.

Several machines have been devised for the production of continuous electric currents upon the principle demonstrated by Faraday, that whenever a mass of metal is made to pass before the poles of a magnet, so as to cut the magnetic curves at right angles, electric currents are produced across the metal, transverse to the direction of motion. In the most convenient of these machines (Saxton's), a powerful current is produced by causing an armature of soft iron to revolve very rapidly before the poles of a powerful horse-shoe magnet. Machines constructed upon this principle have in some cases replaced the voltaic battery for the processes of electro-plating; and it has recently been proposed to employ them for the production of the electric light.

THERMO-ELECTRICITY.

It is interesting to trace a relation between heat and electricity similar to that which has been exhibited between magnetism and electricity. It has been seen that any obstacle to the equal transmission of a voltaic current through a conductor, gives rise to the production of heat, and, conversely, it is found that an unequal transmission of heat through the different portions of a conductor occasions a development of Electricity. This is best seen when two bars of dissimilar metals, such as antimony and bismuth, are soldered together, and heat is applied to the point of junction; a current will then be perceived to flow from the antimony to the bismuth. This fact has received a very elegant application at the hands of Nobili and Melloni, in their investigations upon radiant heat. Their *thermomultiplica*, for measuring very minute differences of temperature, consisted of 36 pairs of small bars of bismuth and antimony, so arranged that the heat to be measured fell upon their points of junction, the current thus excited was then estimated by a very delicate galvanometer; it is said that even the heat radiated from the bodies of insects could be measured by this beautiful instrument.

ANIMAL ELECTRICITY.*

The power which is possessed by some species of fish of imparting electric shocks is probably originated in a similar manner to that in which an ordinary voltaic current is produced. The *gymnotus electricus*, or electric eel, the *silurus electricus*, the *trichiurus electricus*, the *tetraodon electricus*, the *raia torpedo*, and all the species of the genus *raia*, exhibit this electric power. In the gymnotus there are two pairs of electric organs, of different sizes, taking up about one-third of the whole fish: they are formed of longitudinal, thin, membranous septa, crossed by similar transverse

* The following description of the gymnotus, torpedo, and raia, has been transcribed from the article upon GALVANISM by Colonel Portlock, in the preceding edition of this work.

septa. The distance between the longitudinal septa in the large pair of organs, some of which extend nearly the whole length of the body, is, in large fish, nearly half an inch; and between the transverse septa, $\frac{1}{240}$th part of an inch, so that the whole organ is divided into a vast number of cells. The distance between the longitudinal laminæ of the smaller pair of electric organs is only $\frac{1}{20}$th of an inch. These fishes vary in length from 3 to 4 feet, and so great is the power of the shock, that horses are stunned by it; the animal has not the power of keeping up a continued succession of shocks, so that in South America they are captured after having allowed them to exhaust their electric energy upon horses driven into the pools where they abound. The anterior portions of the fish are positive to the posterior, so that the most powerful shocks are imparted when it is touched simultaneously near the head and tail. In the torpedo there is an electric organ on each side, situated between the cranium and gills and the cartilage of the great pectoral fins; they are about 5 inches long, 3 inches broad in front, and about half an inch broad behind, extending from the anterior extremity of the animal to the transverse cartilage which divides the thorax from the abdomen. Above and below, the electric organ is covered by a fibrous membrane, and at the sides it is closely connected with the skin, having a second fibrous layer, the fibres of which are transverse to those of the first, under it. The organ within these membranous coats is formed of perpendicular columns, reaching from the upper to the under surface of the body. The diameter of the columns is about $\frac{9}{10}$ths of an inch, and their figure irregular, varying generally from the hexagon to the pentagon; the coats being very thin and transparent, and the columns closely connected together by a kind of loose network of tendinous fibres passing transversely and obliquely between the columns. The columns are divided by horizontal partitions, placed at very small distances, and forming numerous interstices. The number of columns in each organ of a torpedo 18 inches long, was 470; and in one $4\frac{1}{2}$ feet long, 1182; and the number of transverse partitions in one inch, 150. The numerous cells of both the gymnotus and the torpedo are filled with a gelatinous fluid, and the nerves connected with them are both numerous and massive. This latter consideration of the great amount of nerves bestowed upon these organs, and the fact that the animal can give or withhold the shock at will, afford strong support to the opinion that the apparatus is charged by an instantaneous nervous excitement, and the temporary loss of the power by exhaustion corresponds to the ordinary debility consequent upon any too long continued exercise of nervous power. The researches of M. Robin have shown that in the ordinary rays, so closely allied to the torpedos, the electric organs do exist, but not in the position assumed by preceding anatomists; they are placed on each side of the tail, are about the thickness of the index finger, and 13 inches long. Each organ is a flattened cylinder, formed of longitudinal piles of polygonal discs, arranged in layers from two to four in number. The discs are separated by a gelatinous tissue similar to that of the columns of the torpedo and of the cells of the gymnotus.

The experiments of Matteucci have elicited a fact of great importance to the physiologist, viz. that in every animal a current is perpetually circulating between the internal portion of a muscle and its external surface, probably excited by the chemical actions continually occurring in the muscular fibre. A little battery constructed of the thighs of frogs, was found to produce a deviation of the galvanometer needle.

The electricity developed by voltaic action (*dynamic electricity*) appears to be identical in its nature with the electricity obtained from the machine (*frictional*, or *static electricity*); but its quantity is vastly greater, and it is consequently much

more able to effect chemical decomposition, though its intensity is very much lower than that of the machine-electricity, and therefore it does not pass so readily through non-conductors in the form of sparks, unless its intensity is much exalted, either by increasing the number of cells in the battery, or by causing it to induce a secondary current. It has been calculated by Faraday, and confirmed by Becquerel, that the decomposition of a single grain of water, which may be effected by one voltaic pair, would require 800,000 discharges of a Leyden battery exposing 3500 square inches of coated surface.

The study of voltaic electricity, more than that of any other branch of experimental science, brings prominently before the mind the correlation and mutual dependence of what we are in the habit of calling the different varieties of force. We there learn that heat, electricity, magnetism, and chemical action, are so intimately connected, that one being given, all the others may be developed from it; either of these forces may also be made to furnish light, though the converse relation is not yet in every case so clearly established. This consideration holds out to us some expectation that the unity of force may hereafter be demonstrated; and a further extension of our knowledge of the mutual dependence of different forces, even should it fall short of this, could not fail to strengthen our command over material phenomena, and to lead to fresh discoveries, contributing to human welfare and advancement.

GEOGNOSY AND GEOLOGY.*—The actual meaning of the first of these terms, is a knowledge of the earth, and of the other, a treatise or discussion tending to promote such knowledge; hence it is natural that they should have often been used to designate the same inquiries: at present it is more usual to signify by the term Geognosy, a study of the nature, characteristic differences, modes of arrangement and combination and distribution of rocks; and by Geology, a study of the phenomena (whether exhibited in the mineral, vegetable, or animal kingdom) connected with the formation and subsequent modification of those masses, stratified or unstratified, of mineral matter which constitute the crust of the earth. These two branches of inquiry are however so intimately connected with each other, that although it may be possible to acquire a competent knowledge of the actual composition and general nature of rocks without studying the laws which have regulated their formation, it is certainly impossible to understand fully the formation, modification, and disturbances of that portion of the earth's crust which comes within the scope of observation, without having previously acquired a knowledge of the composition and qualities of the rocks or strata which compose it. In this brief sketch, therefore, of the science, those parts of each branch of inquiry will be combined together which are considered essential to the successful application of theory in practice.

If we look at Geology in the widest sense of the term, it appears to us a science intimately connected with the highest branches of physical research. The earth, as one of the planetary bodies revolving round the centre of our solar system, must, like all the other planets, be subject to the great laws by which they are retained in their orbits and caused to revolve on their axes; it is, in short, only one member of a great whole, and in its density, its volume, and its mass, is in strict relation to all the other bodies of the system. The first formation, therefore, of the earth, or the

* By Colonel Portlock. R.E., F.R.S., F.G.S.

manner in which it is probably condensed from nebulous matter, and reduced to the planetary form, may be considered a portion of Astronomical science. And if we leave this sublime inquiry, and enter upon the more practical investigation of the present state of the earth's surface, we are soon convinced that there is something more in the rocks and strata we discover than mere masses of stone or heaps of gravel, sand, or mud, confusedly thrown together: we find, in fact, that these deposits have been the result of forces tending, according to the laws of nature, either to break up and remove, or to deposit and consolidate in new forms the mineral strata, and our science is thus connected with the experimental sciences of Meteorology and Chemistry.

Nor is this all; for whilst we examine the mud and sands of our own coasts and seas, and find imbedded in them, or resting upon them, the relics of many living species of animals and plants, we cannot overlook the analogy as to distribution and arrangement exhibited by the sandstones and clays of other epochs, and the wonderful fact that they too are associated with the relics of organic beings. It is here then that we learn the close connection of Geology with the natural sciences, and are taught to view that science, which may at first have appeared to us a humble investigation only of the circumstances of inert matter, in the lofty character of an expounder of the mysteries of organic creation.

Thus much has been said in order to impress upon the reader the philosophical importance and dignity of Geology: and that it practical importance is the result of its philosophical connection with the exact sciences, will now be shown.

Let it be first premised, that a science is practically valuable just in proportion as its laws have been studied and established. So long as we are uncertain whether a known result has proceeded from a definite cause, we are unable to apply the fact or circumstance to the elucidation of other facts or circumstances; and so long as we are unacquainted with the properties of any substance under our examination, we cannot declare with certainty what share it may have had in the phenomena we have observed. This may be illustrated by a reference to gunpowder. Its explosive quality is the result of its composition, and we can only depend upon the results when we know that the compound has been accurately formed; to ensure, therefore, certainty in our operations with it, we must take care that a proper standard of composition has been adhered to. In a similar manner we can only apply Geology as a practical science, when we have ascertained and made ourselves familiar with those facts which prove the first principles, on which it has been built up, to be correct and stable.

For example, were all the deposits we meet with, here rock and there sand, gravel, and clay, mere arbitrary heaps which had never been brought under the controlling influences of organic or inorganic forces, we should be unable to use the one as an index to the history of the other, and the study of each individual deposit would end as it had begun, in itself alone. But if it be proved that certain physical agencies have, according to fixed laws, been in operation from the earliest periods of our planet's history, and that they have either co-operated with, or acted upon, organic beings, so as to check, modify, or destroy, at successive times, the course of animal and vegetable life,—and if in the strata themselves we can find the fossilized relics of such successive races of organized beings, and be enabled to make the one a guide to the other,—how different is the result, as uncertainty now gives place to certainty, and a knowledge of the strata of one portion of the earth's crust becomes a clue in the investigation of those of any other! It is upon this certainty, obtained by the collection and collocation of facts from all parts of the world, that Geology rests its claim on the attention of practical men; and it appears unnecessary to seek for

arguments in urging our brother Officers to study a science at once rich in facts of the highest interest, and capable of the most important practical applications. As briefly then, as possible, will be explained—

1st. Those theoretical deductions which, proceeding from the observation of facts, have resulted in the establishment of what are called geological formations.

2nd. The practical application of the theory.

In order to acquire a clear conception of geological phenomena, it is necessary to take a brief review—1st, of the various elementary substances which enter largely into the composition of the earth's crust, and of the fluids connected with it; and 2ndly, of the principal compounds formed by them.

Including most of the metals, there are more than fifty substances which, having as yet resisted the efforts of the chemist, still appear to our senses simple; of which sixteen only occur extensively amongst ordinary mineral compounds, whether fluid or solid. They are, *oxygen*, *hydrogen*, *azote* or *nitrogen*, *chlorine*, *fluorine*, *carbon*, *sulphur*, *phosphorus*, *silicium*, *aluminium*, *potassium*, *sodium*, *magnesium*, *calcium*, *iron*, and *manganese*, which, combined together in various ways, compose the greater portion of the earth's crust and of its liquid envelope.

The other elementary substances, though several of them, as bromine, iodine, and boron, are highly interesting, and some, as the metals, are most important, do not constitute a portion of the whole sufficiently great to require a specific notice in this part of our subject.

The important offices of some of these substances are generally known; as, for example, of hydrogen and oxygen in water,—of oxygen and nitrogen in air,—of carbon as a minute but very essential constituent of air,—of carbon again as a combustible substance in turf, wood, and coal,—of iron as the most useful of metals; but in addition o these well-known offices, they have others, little less essential and marked, to perform in the mineral constitution of the earth's surface, as it is by the combination of the metallic and non-metallic elementary substances that the minerals of which its great bulk consists are formed: considering these substances in order, this first great fact will become evident.

Oxygen combines with silicium to form silica, of which it constitutes more than a half; but silica, either pure or combined as an acid with metallic bases, has been estimated to form almost one-half of the solid crust of the terrestrial globe; and hence oxygen, in this one condition, is equivalent to a quarter of the ponderable matter of the earth's surface. But oxygen is also combined with aluminium to form alumina, an earth which is an essential constituent of certain minerals and rocks, the decomposition of which produces the beds of clay so general throughout the world: and, when the quantity of mud or clay found in modern alluvium, and the beds of clay in more ancient deposits, are considered, as well as the strata of mica and clay slate, of great thickness and extending over miles of the earth's surface, in all of which alumina is an essential ingredient, the several varieties of clay being essentially silicates of alumina proceeding from the decomposition of the felspar and mica of granite, gneiss, mica slate, and clay slate, the importance of alumina must be considered only second to that of silica; but of this earth, oxygen in weight forms nearly one-half.

Again, of carbonate of lime, the basis of limestone, a mineral constituting in many parts of the world mountain masses of many hundreds of feet thickness, oxygen forms also nearly one-half; so that if we add to these instances of its presence that of water, so abundant in the mineral as well as the vegetable and animal kingdoms, and of which it forms in weight eight-ninths, we may readily believe that of the whole crust of the earth, at least one-half is composed of this remarkable element.

Hydrogen, as a constituent of water, enters into the composition of many minerals and mineral strata, and forms a part of almost every organic substance.

Azote or *nitrogen*, as a constituent of the atmosphere, of most animal, and of several vegetable substances, is an important element, although it is scarcely appreciable in the mineral kingdom. Traces of this fundamental element of animal organization are however to be observed, in the form of ammonia, in those strata wherein were deposited the remains of animals, and such traces have been sometimes appealed to as a test of the former presence of animals in strata which now exhibit no fossil evidence of their existence; but however striking this exhibition of ammonia may be, it is subject to so many sources of uncertainty, as to be justly considered insufficient in deciding so obscure and difficult a question.

Carbon, the basis of coal, the base of carbonic acid, and the most considerable element of the solid parts of animals and vegetables, is one of the most important substances in nature; it forms nearly one-eighth part of carbonate of lime, and is therefore an essential constituent of the earth's crust.

Sulphur, though a constituent of many organic substances, is exhaled in large quantities from volcanoes, either in a pure state or in combination with hydrogen, and has evidently therefore proceeded from some of the mineral substances with which they are connected. Sulphur is also visibly a part of the mineral kingdom, as it occurs in the sulphurets, in sulphate of lime or gypsum, in sulphate of baryta, strontia, etc.; but as regards the sulphurets, its presence is often only secondary, being the consequence of the partial decomposition of the sulphuric acid of soluble sulphates. And here may be noticed the singular chain of composition and decomposition exhibited by this substance. In beds of shale, iron pyrites (bisulphuret of iron) is frequently very abundant, and when water gains access to it, there is a partial decomposition, some of the oxygen of the water combining with the sulphur to form sulphuric acid, which then combines with the iron, also oxidized from the water, to form sulphate of iron. This soluble salt is carried away by the filtering water, and when it comes in contact with animal or vegetable substances imbedded in the strata, is again decomposed, the oxygen going to the hydrogen and carbon of the organic bodies, and a sulphuret of iron being deposited in their tissues. The results of this process, as exhibited in fossil vegetables and in the organic portions of shells and fish, are sometimes very beautiful, and it may be doubted whether the succession of compositions and decompositions has yet been traced up to its first commencement in the more ancient geological strata.

Phosphorus.—A constituent of phosphate of lime, a rather rare mineral as Apatite, in the mineral kingdom, but a most important one in the animal kingdom, as being the mineral portion of bone, the strength and stability of which depend upon it. It is also a constituent of many vegetables, and *from them enters into the animal structure.* Darwin mentions two curious secondary productions of phosphate of lime,—one at St. Paul's Islands, where the rocks are coated with it, the action of the spray on the dung of seafowl having produced phosphoric acid, and at Ascension, where stalactites of the same mineral have been produced in a similar way.

Chlorine, as a constituent of chloride of sodium (common salt), takes part in the formation of those extensive beds of rock salt which occur in various geological formations. Chlorine forms nearly $\frac{7}{12}$ths of chloride of sodium, and is therefore another example of a gaseous body entering extensively into the composition of the earth's crust.

Fluorine, like chlorine, combines directly with metals, and forms fluoride of calcium, fluor or Derbyshire spar, commonly called fluate of lime. It is often found associated with lead in vein-stones. It is also a constituent of mica and of hornblende,

but it may be considered important rather in a mineralogical than in a geological sense.

Silicium or *Silicon*, a metal of which silica is the oxide.—The important position this substance occupies has been shown under 'Oxygen;' most of the minerals, exclusive of the carbonates and sulphates, which form the earth's crust, appearing in the form either of silex or of silicates. The water of springs and wells always contains a little soluble silica: in mineral waters its quantity is sometimes more considerable, and associated with an alkaline carbonate, it occurs in the hot alkaline spring of Reikum, in Iceland, and in the boiling jets of the Geyser. These latter modes of occurrence, whilst they indicate the slow but continual destruction of the silicates of the mineral kingdom, give a useful hint as to the probable formation of much of the crystalline quartz in nature.

Aluminium, a metal of which alumina is the oxide.—Alumina, as one of the principal constituents of clay, and of all those minerals and rocks from the decomposition of which it is produced, is, as shown under 'Oxygen,' a most important portion of the earth's crust. It is also well known as one of the component parts of alum, a salt so extensively used in dyeing, which is a double sulphate of potash and alumina. The sulphate of alumina is formed naturally by the action of sulphuric acid, proceeding, as already stated, from the decomposition of iron pyrites (bisulphuret of iron) on the beds of clay or of shale in which that mineral is abundant. The sulphate of alumina being dissolved out, and separated by crystallization from the proto-sulphate of iron formed at the same time, is mixed with sulphate of potash, and the two combine to form the double salt alum. Alum-stone, a natural product of volcanic countries, also yields, by heating, this substance: it is abundant in the ancient crater of Solfatara, near Naples.

Potassium, a metal of which the alkali potash is an oxide.—Potash is a component of many minerals, especially of felspar (a well-known constituent of granite and gneiss), of which it forms nearly $\frac{1}{6}$th part. Potash in this mineral is in the condition of a silicate, and it is from the decomposition of rocks containing felspar that the soil is provided with the potash necessary for the support of various plants. From the artificial destruction of these plants, the potash is obtained for use in the arts, and has therefore obtained the name of vegetable alkali from the source of its secondary production. It is the base of the important mineral compound, nitre or nitrate of potash, which will be further noticed.

Sodium, a metal of which soda is an oxide.—This alkali replaces potash in albite (soda felspar). Soda has been called the mineral alkali, in contradistinction to potash, but such a mode of distinction is now known to be groundless. Carbonate of soda is obtained from kelp, or the ashes of calcined sea-weeds, and might therefore, as a secondary production, be also called vegetable. Soda is likewise found in all animal fluids, and the base itself is widely diffused in that most valuable salt, the chloride of sodium, or common salt. Nitrate of soda abounds in Peru.

Magnesium, a metal of which the earth magnesia is an oxide.—Magnesia, as a silicate, is a component of many important minerals, especially of pyroxene or augite, of amphibole or hornblende, of steatite, and of serpentine. Of hornblende it forms $\frac{1}{8}$th part. It is also remarkable as a carbonate in dolomite, or magnesian limestone, a combination of the carbonates of lime and magnesia which is very extensively diffused in nature, and forms occasionally mountain masses. The effect of magnesia on vegetation is well known. As a carbonate, it would in itself perhaps be innocuous, but as it is liable to be decomposed and to form very soluble salts, it may be carried into the vegetable organism, and thereby prove injurious. As an alkaline earth it is dangerous from continuing so long in a caustic state.

Calcium, the metallic base of the earth lime, which forms more than a half of carbonate of lime.—It is unnecessary to dwell on the vast importance of the latter mineral, both as an economical substance and as a constituent of the earth's crust; but lime is also found as a component of another valuable mineral—sulphate of lime, or gypsum, of which it forms about $\frac{1}{4}$th part. Gypsum occurs in extensive beds in more than one geological formation; in America in the primary or Silurian, in England and Ireland in the secondary, and along the Mediterranean in the tertiary strata, divisions which will be hereafter explained. Lime also enters into the composition of a great variety of minerals.

Iron.—The mere name of this metal must recall to memory the multitude of uses to which it is applied, and justify us in regarding it as one of the greatest gifts of creative intelligence to man. In addition, however, to its occurrence in a mineral state in our coal measures, as clay iron-stone, and also as spathic iron, both of which are carbonates of iron, in masses and in disseminated nodules as anhydrous and hydrated peroxide of iron, or red and brown hematite, in the magnetic oxide and in specular iron, or Elba iron,—minerals which as ores are smelted for iron,—it is found almost pure in masses of meteoric iron and in a vein traversing mica slate in North America. In combination as an oxide, it is extensively diffused, being found in small quantities in most minerals, and consequently in the soil of the earth's surface. It occurs in many springs, being dissolved as a protoxide by water charged with carbonic acid, and then again deposited as a peroxide, either at the bottom of marshes, as bog iron, or on the banks of the springs: but it is deserving of notice that this apparently simple operation is, in reality, often compound; the tangled masses of this substance, so frequent in such situations, proving, on examination, to be the work of an infusorial animal,—the gaillonella ferruginea,—which thus interposes and reduces the mineral to an animal substance. In the colouring matter of the blood, of the hair, and of many other tissues, both animal and vegetable, this metal is also found, and its uses are not therefore limited to the great works of art,—the machinery of civilized social life,—but are traced also in the many charms which are shed over life itself by the varied colours assumed, under the control of creative power, by the petals of the flower, the egg and feather of the bird, or the skin of man and other animals.

Manganese enters into the composition of a great number of minerals, though often in a very small quantity, forming, in such cases, their colouring matter. It is also found in the ashes of plants and the bones of animals. It is used in the arts; for preparing chlorine by the action of its peroxide on hydrochloric acid, oxygen by the action of the same oxide on sulphuric acid, to render glass colourless by its oxidating action, and as a deutoxide to colour glass purple.

These then are the simple elementary substances which have been combined together in that portion of our globe which, by the long-continued action of meteoric agencies, has been reduced to a condition suited for the support of animal and vegetable organization: they will now be considered as constituents of the compounds which form the strata of the earth, and which we shall find also to be few, nor is this surprising, when we reflect how many animal and vegetable substances, many of which are possessed of the most opposite qualities,—some being alkalis, some acids, some poisons, some wholesome food,—have been compounded out of the four simple elements, carbon, oxygen, hydrogen, and azote! There is, however, one point deserving especial notice, as bearing on the great question of the former condition of our globe; namely, that so large a proportion of the ponderable matter of the earth's crust, taking into consideration oxygen, hydrogen, and carbonic acid, or about $\frac{2}{3}$rds in all, should have existed, or been capable of existing, in a gaseous state.

2. The minerals which enter into the composition of rocks, and of stratified deposits, are few; namely,—quartz, felspar, mica, augite, hornblende, oxidulated iron, carbonate of lime, sulphate of lime, double carbonate of lime and magnesia or dolomite, chloride of sodium or rock salt, coal, and lignite. Many other minerals occur occasionally in rocks and sedimentary deposits, and impress upon them a consequent peculiarity, such as the garnet in mica schist, the tourmaline in some varieties of granite, flints in chalk and other calcareous formations, iron pyrites (bisulphuret of iron) and carbonate of iron in shales, crystallized carbon or the diamond amongst the gravel and other transported or alluvial matter along the Ghauts in India (especially at Golconda), as also in Borneo and in Brazil; but these, as well as the vast variety of minerals found in the basalts or lavas of ancient and the trachytic lavas of modern volcanoes, and those either associated with metallic ores or isolated in mineral veins, although replete with interest to the mineralogist, and often of great value to the carefully inquiring geologist, are insignificant as to quantity, when compared with those cited as the principal constituents of the earth's crust.

The composition of these minerals may be represented in a tabular form.

Species and Variety.	Silica.	Alumina.	Lime.	Magnesia.	Potash.	Soda.	Oxide of Iron.	Oxide of Manganese.	Carbonic Acid.	Sulphuric Acid.	Water.	Fluoric Acid.	Lithia.
Quartz (when pure) .	100	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,
Felspar (green, of Siberia)	62·83	17·02	3·00	,,	13·00	,,	1·00	,,	,,	,,	,,	,,	,,
Do. (Carlsbad) . . .	64·50	19·75	trace.	,,	11·50	,,	1·75	,,	,,	,,	0·75	,,	,,
Do. (soda or Albite, of Finbo) . . .	70·48	18·45	0·55	,,	,,	10·50	,,	,,	,,	,,	,,	,,	,,
Do. (Albite, of Chesterfield) . . .	70·68	19·80	0·23	,,	,,	9·06	,,	,,	,,	,,	,,	,,	,,
Mica, or talc-mica, (Zinnwald) . .	47·00	20·00	,,	,,	14·50	,,	15·50	1·75	,,	,,	,,	,,	,,
Do. (2nd Zinnwald variety) . . .	46·23	14·14	,,	,,	4·90	,,	17·97	4·57	,,	,,	3·73		4·21
Do. lepidolite (granular or scaly mica)	50·35	28·30	,,	,,	9·04	,,	,,	1·23	,,	,,	5·20		5·49
Augite (green) . . .	54·08	,,	23·47	11·49	,,	,,	10·02	0·61	,,	,,	,,	,,	,,
Do. (black) . . .	53·36	,,	22·19	4·99	,,	,,	17·38	0·09	,,	,,	,,	,,	,,
Hornblende (green, Pargasite) . . .	46·26	11·48	13·96	19·03	,,	,,	3·43	0·36	,,	,,	,,	1·60	,,
Do. (black)	45·69	12·18	13·85	18·79	,,	,,	7·32	0·22	,,	,,	,,	1·50	,,
Oxidulated iron . . .	,,	,,	,,	,,	,,	,,	peroxide, 2 atoms; protoxide, 1 atom.	,,	,,	,,	,,	,,	,,
Carbonate of lime (when pure, as calcareous spar) . .	,,	,,	55·93	,,	,,	,,	,,	,,	43·58	,,	,,	,,	,,
Sulphate of lime (gypsum)	,,	,,	33·00	,,	,,	,,	,,	,,	,,	44·80	21·00	,,	,,
Do. (anhydrite) . . .	,,	,,	41·75	,,		muriate, 1·00	,,	,,	,,	55·00	,,	,,	,,
Dolomite (by Thompson)	,,	0·68	30·54	22·91	,,	,,	1·69	,,	48·22	,,	,,	,,	,,

Pure rock-salt may be considered a compound of sodium 40·5 and chlorine 59·5, but it is usually contaminated by a small quantity of extraneous substances; the salt of Cheshire containing:—

Muriate of soda	98·32
Muriate of Magnesia	0·02
Muriate of lime	0·01
Sulphate of lime	0·65
Undissolved matter	1·00

Coal and lignite in like manner exhibit a great variety as to purity, and even as to the condition of their substance. Blind coal, culm, or anthracite, contains for example from 94 to 97 per cent. of carbon mixed only with mineral matter, as no bitumen has been developed in it, though traces of vegetables have been discovered even in anthracite: this therefore is a non-flaming coal, and yielding an intense heat, is particularly valuable for the lime-kiln and similar purposes. The Kilkenny coal of Ireland and the culm of Wales belong to this division. Newcastle coal is on the contrary a flaming or bituminous coal, consisting, in the best varieties, of carbon 84·99, hydrogen 3·23, oxygen 11·78, bitumen having been developed in its substance by the action of oxygen and hydrogen on a part of its carbon. Lignite still exhibits the structure of wood, and may be considered a fossil charcoal.

In looking at the Table, a substance will be observed, not named in the list of principal elementary substances, its quantity being small in the composition of rocks, namely, lithia, an alkali which has obtained its name from the Greek λίθειος, as being first derived from an earthy mineral. The metal lithium was obtained by Davy from this alkali: its equivalent is very low, 6·44, and its oxide has therefore a high saturating power. The discoverer of the alkali was Arfwedson, in 1818.

It is right also to draw attention to the variation of the quantities of elements in varieties of the same mineral, a fact constantly occurring in mineralogy, and explained by the chemical theories of equivalents and isomorphism. This latter doctrine is founded on observation, and means, that substances possessing the same elementary constitution may replace each other in a mineral, without disturbing its principal or characteristic qualities; for example, alumina is possessed of the same elementary constitution as peroxide of iron, namely, it consists of 2 of base to 3 of oxygen, and can thus replace it; and magnesia, possessing a constitution of 1 of base to 1 of oxygen, can replace the protoxide of iron. In green and black augite this is well exemplified by the proportions of the bases: as,

Green augite,—magnesia 11·49 + prot. iron 10·02 = 21·51
Black augite,—magnesia 4·99 + prot. iron 17·38 = 22·37;

and it is thus that the chemical composition may often vary, and yet the formula of composition be preserved.

The physical characters of these minerals it is difficult to convey fully to the mind by written description, and it is recommended to the student to obtain accurately named specimens. The following remarks may however be of use when combined with the subsequent description of rocks.

Quartz is well known both as rock-crystal, which is often called diamond, as Cornish diamond, Bristol diamond, Quebec diamond, although having no relation to that mineral, and as common quartz. The prevalent colour is white: when pure it is either transparent or translucent; when impure it is commonly opaque. Its lustre is vitreous, inclining in some varieties to resinous. The streak is white, and the fracture curved or conchoidal.

Felspar.—Prevailing colour, white, sometimes grey, and in many granites and syenites flesh-red: transparent, translucent, or almost opaque; lustre vitreous, inclining to pearly on the faces of cleavage.

By observing the tendency to a resinous lustre in quartz, and to a pearly lustre in felspar, these two minerals may generally be distinguished from each other without difficulty.

Mica.—Prevailing colour, white, grey, yellow, dark brown, or black; transparent and translucent, especially in thin laminæ; lustre, pearly; flexible and elastic when in laminæ, by which character it is distinguished from chlorite and talc. This remarkable mineral is at once recognized in granite, gneiss, and mica slate, by the brilliancy of its plates or laminæ.

Augite.—Colour varying from green or grey to brown and black; generally opaque; lustre vitreous, inclining to resinous; brittle. This is a very common product of volcanic rocks.

Hornblende.—Prevalent colour, shades of green extending up to black; generally opaque; lustre vitreous, inclining to pearly in light-coloured varieties. Brittle when isolated, but when massive it is frequently tough, and therefore with difficulty frangible.

The two last-named minerals are reducible to the same chemical formula, as they are both bisilicates of lime and magnesia, in which a portion of the acid or silica is sometimes replaced by alumina, and a portion of the base by protoxide of iron, according to the law already noticed; but they afford an example of dimorphism, as the crystalline forms are different. Hornblende is an essential ingredient of syenite and greenstone, and occurs frequently in granite, gneiss, and other mountain rocks, and this general difference of geological position will naturally lead the inquirer to judge in most cases whether he is looking at the one or at the other; but as it is sometimes very difficult to determine whether a rock should or should not be classed with greenstone or with basalt, it is also sometimes difficult to distinguish between these two minerals. In general the species hornblende contains less lime than augite, and is also less fusible; but, as might have been supposed from the similarity of their elementary constitution, it is possible, under certain conditions of heating and cooling, to change the external crystalline form of the one into that of the other,—a fact which has been used to explain the difference of their ordinary position.

Oxidulated Iron or *Magnetic Iron.*—A compound, according to Berzelius, of 2 atoms of peroxide and 1 atom of protoxide of iron. It is highly magnetic, and when massive, more so than any other ore of iron. Colour, iron-black; opaque; lustre, metallic. It forms extensive beds in Norway and Sweden: at Dannemora the beds are excavated to the day, the principal mine forming a chasm of one hundred and fifty feet broad, and five hundred feet deep. The amorphous masses of Siberia and the Hartz, which yield the most powerful natural magnets, may be associated with this species.

Carbonate of Lime, and also Double Carbonate of Lime and Magnesia.—The presence of carbonic acid can always be determined by the action of an acid and the consequent ebullition produced by the escape of the carbonic acid. This is the easiest and most certain method of detecting the various species of limestones.

Sulphate of Lime.—Distinguished from carbonate by not effervescing with acids; and from other minerals, whether in its fibrous or lamellar state, by its comparative softness.

Of salt, coal, and lignite it is unnecessary to say more under this head.

We have now passed in review the more ordinary geognostic minerals, and are prepared to inquire under what combinations they are usually presented to our observation.

A survey of any extensive portion of the earth's surface will generally bring before us two distinct forms of mineral matter; the one, in which the mineral constituents are combined together in distinct crystals, which to the eye exhibit no traces of any previous wear, and produce therefore crystalline or subcrystalline rocks; the other,

in which the constituents have undergone wear, are either mixed together confusedly or separated into distinct beds, but whether loosely aggregated or cemented together, betray the action of various meteoric and mechanical agencies, producing rocks evidently of deposition, whether mechanical or chemical. To the first class belong—granites, syenites, greenstones, basalts, gneiss, many varieties of mica-slate, granular limestone. To the second—sandstones, conglomerates, shales, clays, compact limestones; and if these forms were always so marked as in the examples cited, the divisions would be sufficient and satisfactory; but it is impossible to examine the crystalline rocks, formerly called primary, without finding in some of them a condition closely approaching to the sedimentary, as, for example, in the mica slate division, in which the clay slate varieties are sometimes little more than a highly indurated shale; or to look at true sedimentary rocks in the vicinity of ancient lavas without observing their change into a condition which nearly places them in a crystalline division: for example, the lias shales of Portrush in Ireland have undergone this change to such an extent, that they were at one time considered a portion of the basaltic field, and were only separated from it when the presence of ammonites of the lias had combined with their evident stratification to remove them to their proper place. The result of such observations has been the establishment of the metamorphic theory, which will be again referred to at a future stage of our subject.

In the preceding paragraph, allusion has been made to the occurrence of ammonites in the indurated or, more properly, metamorphosed shales of the lias of Portrush in Ireland. This mixture of the remains of organic bodies with ordinary mineral matter is no casual fact; it has been proved to occur in almost every portion of the globe, and has been traced through so extensive a series of strata, as to have necessarily connected the study of the animal and vegetable with that of the mineral kingdom. Nor has this study been without its fruits, as it has not only proved that the geographical range of types of organic beings still existing in nature has varied at successive periods, but it has also brought to light new types, no longer existing, which serve to prove a variation of the conditions of the earth's surface at successive epochs.

If now we combine the three modes of studying the earth's crust, we shall find that the one will illustrate the other, and that together they will enable us to form a reasonable history of the changes it has undergone. It is not however the aim of the geologist in such researches to go back to final causes, as he well knows that a science of observation can only trace the laws, or modes of action, agreeably to which they have been developed. He feels indeed a conviction impressed upon his mind, by a multitude of facts, of the necessity of a Great First Cause, but at the same time he is forced to acknowledge that the nature of that Cause can only be learnt by a revelation from itself of its own essence.

Returning, for example, to crystalline rocks: the existence of definite minerals combined together in crystalline forms is most readily explained by supposing that they were previously dissolved by a solvent; and Werner therefore, discarding the theory that crystalline rocks were only a portion of the original mass of the earth cooled down, assumed that they also had been dissolved by a fluid menstruum, and subsequently precipitated in the form of beds; the whole superficial crust, which does not exceed on an average in thickness $\frac{1}{1000}$th part of the earth's radius, being therefore of secondary origin.

The principal reason why the disciples of Werner so long adhered to this opinion, was the difficulty of drawing any line of demarcation between strata manifestly of aqueous deposition and those in which there are now no traces of such deposition; and it was even urged, that beds containing fossils were so closely asso-

ciated with the crystalline, that they could not with any reason be separated from each other. The theory of Sir J. Hall, applied on true metamorphic principles, removes the difficulty. The accumulation, through a vast series of ages, of detritic matter, proceeding from the decomposition and wear of original rocks, may have entirely concealed those rocks, but yet that accumulation must have had a beginning, and it is very probable a beginning anterior to the creation of any organic beings; and if so, it is not unreasonable to suppose that portions of crystalline rocks, formed by the gradual cooling of a once fluid mass, may have been removed by the wearing agents, and deposited in beds below the primeval ocean, and that these beds, acted upon under the pressure of the superincumbent fluid by the great remaining heat of the earth's mass, should exhibit that return to a homogeneous crystalline arrangement which the observation of a vast number of similar facts has shown to occur when sedimentary beds have been acted on by ancient or modern lavas. The metamorphic theory therefore removes Werner's great objection to the application of recent analogies in explaining the condition of crystalline rocks, and we are enabled to state that crystalline rocks may either be the result of direct igneous action, producing a species of fluidity, as in lavas, and probably in some granites and porphyries; or of the indirect action of heat acting for a long period and under pressure on sedimentary deposits, and tending to promote or facilitate the re-arrangement of the mineral particles into a crystalline or semicrystalline condition, as has been the case in the crystalline schists and in some other strata the physical condition of which has been altered, although the existence of organic bodies still demonstrates their former sedimentary character. It is by the careful examination of recent and still recurring natural phenomena that these truths have been made manifest; and it is by the continuance of such examination that any remaining difficulties must be removed in their application; as, for example, it may be suggested that in the great basaltic deposit of Ireland all the beds are probably not eruptive, but, on the contrary, that some are metamorphic, just in the same manner as in the vicinity of modern volcanoes,—of Vesuvius, for example,—where beds of tufa and of ashes are observed covered by streams of lava. The change produced on mineral beds by contact with highly heated matter has indeed been demonstrated, almost with mathematical precision; and though it is very difficult to decide its exact limitation, we can never satisfactorily study the strata of the earth without referring to it. And if the metamorphic theory aids us in explaining the varying mineral conditions of the earth's crust, the organic remains still visibly imbedded in many of its beds demonstrate that changes equally striking have taken place in the successive organic inhabitants of its surface; in short, that there have been animal and vegetable as well as mineral epochs.

The beautiful combination of facts on which Palæontology now rests, as one of the most sure bases of geological science, can only be fully appreciated by careful study; but in this brief memoir it must be assumed to have been studied, and this result arrived at, namely, that at those various epochs of change on the surface of our globe, when the mineral strata were affected deeply and widely, shales and slates, sandstones and conglomerates, limestones, &c., being formed, some in one place, some in another, great modifications also took place in organic beings. If this conclusion be true, and it rests on facts observed over a large portion of the earth, it must be admitted that the evidence of the epochs of mineral change ought to coincide with that of the epochs of organic change, and hence that the study of the one may be made to assist that of the other: a remarkable deduction, which has in a few years elevated Geology almost to the rank of an exact science, and when combined with the results of a more extended study of the operations of all the great forces which are acting

and always have acted on the earth's strata, including magnetism or electro-magnetism, will render it so practically exact, that not only may the probability (under any conditions of strata) of discovering certain useful products be at once premised, but the more abstract and obscure questions of mineral veins and of the distribution of metals be also solved on sound principles.

On the combined testimony of all these facts, it may then be assumed, that as mineral matter in volcanoes is now brought into a state of semifluidity sufficient to allow the crystallization of minerals, so may it at former epochs have undergone a similar fusion, and hence that there is a reason why truly igneous rocks may at such epochs have existed, and have been brought nearer to the surface, or even erupted; that, in a similar manner, the changes produced by slow igneous action under great pressure have been observed in strata contiguous to modern and ancient lavas, and consequently may be fairly admitted to have occurred in strata contiguous to other igneous rocks, giving rise to schistose crystalline rocks in all their varieties, and more or less modifying the structure of many other sedimentary deposits; and finally, that changes in the combinations of organic beings, having been by extensive observations proved to have occurred at successive epochs, a knowledge of the particular group of animals or plants connected with the mineral strata of any one portion of the globe, becomes a clue to determine the relation of such strata with those of any other portion in which the organic constituents have been previously studied. The certainty thus attained constitutes the value of Geology as a practical science; and though there is much yet to do, in order to simplify the lists of characteristic fossils by determining the actual limits of species and distinguishing them from casual varieties, it must be admitted that some of the modern applications of the science have been most striking. A general representation of the combined theories of igneous rocks, metamorphic rocks, and fossiliferous deposits, is given in the ideal diagrams, the first of which I extract from Cotta (Plate I. fig. 1), and fig. 2 from the Transactions of the Geological Society of France.

The preceding remarks will account for the great change which has taken place in the opinions of geologists as to the true character and relation of the rocks once called primary, and will explain the difficulty of forming any simple natural arrangement of rocks which cannot by fossils be associated together in an historical series. The presence of granite veins in the adjacent schists, the frequent disturbance of the schists at or near the points of contact, and the change of structure so often manifest, are sufficient reasons for supposing that the respective rocks which acted and re-acted on each other, must have been in a condition suited for such action—the granite, for example, in a fluid or semi-fluid state, so as to have admitted of its penetrating the schists, and hence that its present consolidation has been subsequent to the existence of the schists in their present positions. Granite therefore, as a rock, must in many instances, if not in all, be considered secondary to the schists; and there is even strong reason for believing with Keilhau that it is often merely the result of a still more perfect change of the schists by which all traces of stratification have been obliterated. The similarity of composition in many of these rocks, although, from difference of crystalline structure, appearing so different, is shown by the following Table, which is compiled from the calculations of De la Beche and Phillips, and partly from my own analysis.

The three columns marked with asterisks are from my own analysis; and the words attached to them, in my 'Memoir on the Geology of Londonderry,' may with advantage be here quoted, as extending their application from greenstones to granites.

Elementary Substance.	Granite: Quartz 2 parts, Felspar 2 parts, Mica 1 part.	Binary Granite: Quartz 2 parts, Felspar 3 parts.	Syenite: Quartz 1 part, Felspar 1 part, Hornblende 1 pt.	Quartz Rock, coloured by Chlorite. *	Greenstone type of Mica Schist. *	Mica Schist, passing into Clay Slate. *
Silica	74·84	75·1	69·91	48·81	51·49	52·45
Alumina	12·80	10·9	10·37	12·58	13·59	12·01
Potash	7·48	9·8	4·55	} 2·89	5·01	3·82
Magnesia. . . .	0·99	0·0	4·86			
Lime	0·37	0·5	6·26	8·81	10·20	7·72
Oxide of iron . .	1·93	0·4	2·69	25·64	18·47	17·92
Oxide of manganese	0·12	0·0	0·07	,,	,,	,,
Fluoric acid . . .	0·21	0·0	0·65	,,	,,	,,
Water	Not estimated.	Not estimated.	Not estimated.	} 1·27	1·24	6·08

"Between rocks closely resembling clay slates with laminar structure and shining appearance, and rocks by external appearance associated with greenstones, there would appear to be little affinity; and yet the composition, as regards the principal constituents, is, as may be seen, by no means so various as might have been supposed; the silica, the alumina, the iron, and the lime, not differing more than is often found to be the case in varieties of the same mineral. A very small alteration or addition of substance is therefore sufficient to place a rock in such a condition as may lead to a most important ultimate change; and viewed in this light, the varieties observable in extensive schist districts possess a very high geological interest."

This simplicity of composition of the crystalline schists approximates them to deposits of sedimentary matter still comparatively unchanged; and as the decomposition of the crystalline rocks must constantly lead to the formation of new beds of sand and of mud, so also at any time may the resumption of the forces which have modified the ancient beds, and reduced them to a crystalline condition, produce a similar result in the recent beds. The term primary cannot therefore be adopted in its original sense, as crystalline rocks, both stratified and unstratified, may be looked for in the formations of all ages. It is not, however, to be supposed that though the peculiar modification of rocks called metamorphic is now generally admitted, the mode in which it has been effected is equally assented to: on the contrary, there are several theories of metamorphosis, each of which has its supporters. In our own country, the long-continued action of highly heated masses acting under pressure, which may be considered the full development of Hutton's original idea, has been adopted as the theoretical explanation of the phenomena of crystalline schists, and the peculiar term 'hypogene' has been proposed by Lyell to express the conditions of metamorphism. In Norway, Keilhau has promulgated a totally different theory, and supported it by numerous facts, the result of a careful examination of the crystalline rocks of Sweden and Norway. In his opinion, the metamorphism of rocks is independent of any igneous action, and is the result of a peculiar action, analogous to the galvanic, taking place at the line of contact between different rocks or strata; and though the proximate cause of such an action cannot be demonstrated by a direct reference to chemical experiments, a similar objection may be urged against the hypogene igneous theory, the alterations of change through an endless variety of species, visible in every great schistose formation, not having been explained by direct experiments, and seeming sometimes contrary to them, as some of the most altered are separated from the supposed focus of change by others far less altered.

But though the theory of change, as deduced from facts, must as yet be considered uncertain, the facts themselves, as detailed by Keilhau, are peculiarly instructive and

interesting. (See Plate II. figs. 4, 5.) Fig. 5 represents a granite vein in the rock called locally 'Norite,' a mixture of felspar, quartz, hornblende, hypersthene, and some mica, having a rudely parallel arrangement. Fig. 4, hornblendic layers in mica schist, Island of Högöe. Without, therefore, asserting that the theory itself of change is established, the crystalline rocks may be temporarily arranged in series, according as the change appears to tend towards some final resulting rock; for example, in the crystalline schists towards either granite or syenite, as by such an arrangement the usual order of facts will be equally well represented, whatever view may be taken of their cause.

Massive Crystalline Rocks.		Stratified Crystalline Rocks, and more simple Strata connected with them.	
Granite . . .	Quartz, felspar, mica.	Gneiss. Mica schist. Clay slate.	Quartz, felspar, mica. Quartz and mica. Crystals become so small that the mass appears homogeneous, though still glistening.
Pegmatite (graphic granite) . .	Quartz, felspar.		
Protogyn . . .	Quartz, felspar, talc.	Talc gneiss. Talc slate.	Quartz, felspar, talc. Quartz and talc.
Syenite . . .	Quartz, felspar, hornblende.	Syenite schist.	Quartz, felspar, hornblende.
Greenstone . .	Felspar, hornblende.	Greenstone schist. Hornblende schist.	Felspar, hornblende. Principally hornblende.
Hypersthene and Diallage rocks	Felspar, hypersthene, or felspar, diallage: hypersthene, anhydrous bisilicate of magnesia, and iron; diallage, hydrated bisilicate of magnesia. Felspar and diallage constitute euphotide; felspar and hypersthene, hyperite.	Hypersthene schist.	Felspar, hypersthene.
Porphyry . . .	Granites, syenites, and other massive rocks, exhibit frequently a porphyritic structure, that is, by the development of isolated crystals in the mass.	Hornstone porphyry. Felspar porphyry. Clay porphyry.	These and many other rocks, including the various crystalline schists, exhibit occasionally the porphyritic character.
Basalt	Felspar, augite. The mixture so intimate, that the separate crystals can scarcely be distinguished: a distinctly volcanic product, still occurring in recent lavas.		Looking at the character of some of the beds associated with the basalt, it is scarcely possible to doubt that many of them are metamorphic, over which at various epochs the basalt has flown, and that similar changes have taken place in them as in other metamorphic strata. Using them as an illustration of the crystalline schists, it may also be suspected that streams of still more ancient lava exist in the close-grained greenstones associated in regular stratification with them.
Dolerite (basaltic greenstone) .	Felspar, augite. The crystals distinct, closely associated with ordinary basalt.	. . . . .	
Ophite	Porphyritic serpentine or green porphyry.		

Massive Crystalline Rocks.		Stratified Crystalline Rocks, and more simple Strata connected with them.	
Melaphyr, or augite porphyry.	Felspar, augite. Rendered porphyritic by isolated crystals of both felspar and augite.	. . . . .	This rock also indicates in part an original schistose arrangement.
Trachyte, or trap porphyry . .	Felspar base, with crystals of glassy felspar; the ancient lava of Auvergne and of the Rhine.	. . . . .	As yet I am not aware of any detailed account of truly metamorphic rocks connected with these.
Andesite . . .	So called from the Andes. The trachytes occur also in the basaltic district of Ireland, so that these two forms of lava are associated together just as the most recent lavas and basalt are.		
Domite . . .	More earthy trachyte.		
Lava, modern .	Including basalts similar to those of more ancient volcanoes.		
Leucite (Amphigène) lava .	Leucite and augite — the former prevailing; this mixture being also rendered porphyritic by isolated crystals of augite and glassy felspar.	. . . . .	Leucite, or amphigène, is a bisilicate of alumina and potash.

In conclusion, as regards these rocks, it may be stated that difference of age, even in the granites, can be distinctly determined in many cases by the rocks which they have either upheaved or broken through: for example, the protogyn, or talc granite of the Alps, has lifted up strata of the tertiary epoch, so that its last movement of elevation must be considered even more recent than the rocks of that comparatively late date. The granite of Cornwall has affected the killas (a slate of that district), and is therefore subsequent in age to the Silurian, in which epoch it is now probable this slate may be classed. The syenites also of the North of Ireland are, from similar reasons, posterior to the Silurian series; and, tracing their action in the formation of porphyritic beds in the old red sandstone, subsequent also to that formation. The granites of Wicklow were probably associated with older rocks, as also those of Down and Cavan; whilst a portion of the basalts of Ireland are, from similar reasons, more recent than the chalk.

But in addition to this stratigraphical mode of determining their age, Leonhard endeavours to draw a distinction between old and new granites from certain peculiar minerals they respectively contain; the tourmaline, for example, which he considers a characteristic mineral of modern granites, and the garnet. If this mode of comparison should be proved correct by more extended observation, the mica schist of Antrim, which is so closely connected with the basaltic rocks of that county, may really be metamorphic of the secondary epoch or of an age not much prior to the chalk. The recent observations of Sir R. Murchison, tending to show that the direction in which mountain chains have been raised has a relation to the minerals and ores developed in their mineral veins or lodes, have also an important bearing on this subject, and may hereafter assist in clearing away the difficulties which yet obscure the history of crystalline rocks.

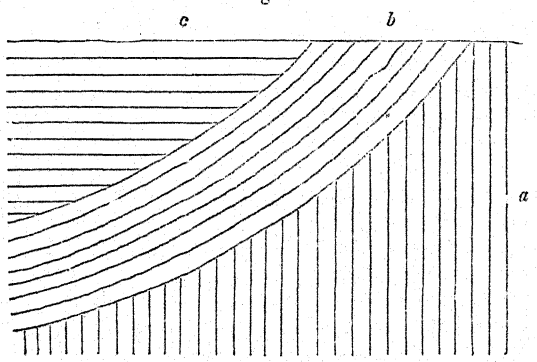
PHENOMENA OF ROCKS.

Before proceeding to the consideration of formations, the relative order of which can only be determined by the study of the natural history of each, that is, by the fossils contained or buried in the successive strata, it is desirable to notice those phenomena, or accidents of strata, the study of which has materially aided in first establishing the fact of their succession, and which must still be carefully studied in all doubtful cases of position.

STRATIFICATION.

Many rocks exhibit a lamellar arrangement throughout their mass, which induces a schistose or slaty structure, sometimes related to the planes of supposed deposition, sometimes to planes intersecting those of deposition, and called cleavage. In the first case, the structure may be connected with original deposition; in the second, it may be due to a subsequent physical modification. In all cases where rocks are observed to consist of distinct layers, lying one over the other, and each having a considerable extension, they are said to be stratified. If stratification had been found uniform in all places, it might have been assumed that deposition had gone on regularly and without disturbance; but as stratification is often very irregular, both as regards the thickness of the beds and their position and direction, it must be admitted that some cause has interfered to disturb and modify deposition. Again, when to a succession of beds having a considerable inclination, called dip, to the horizon, succeed other beds, perfectly or nearly horizontal, it may be reasonably concluded that the first beds must have acquired their tilted-up arrangement before the deposition of the undisturbed horizontal beds, an epoch of disturbance or separation being thus established. The terms conformable and unconformable are applied to strata which either preserve or which lose their parallelism.

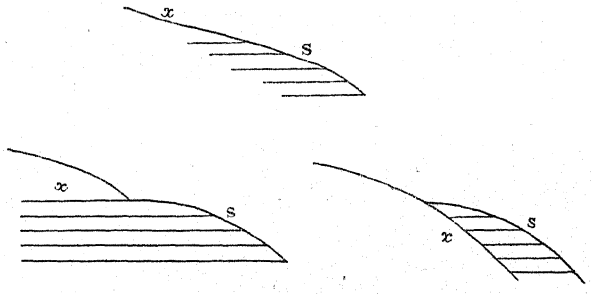
Fig. 1.



Thus *b* is unconformable to *a*, and *c* is unconformable to *b*; whilst the beds of *a*, *b*, and *c*, are conformable within themselves.

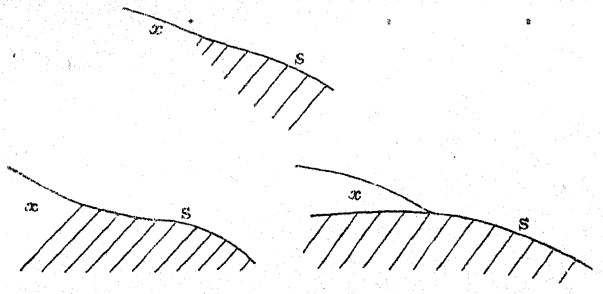
The true position of every bed or stratum, as part of a system, must have been originally determined by a reference to the actual order of superposition, although its imbedded fossils may afterwards have been used in clearing up the obscurities of stratification; and hence the great importance of accurately studying stratification, which is sometimes done not without difficulty, as will be seen by the following examples:—

Fig. 2.



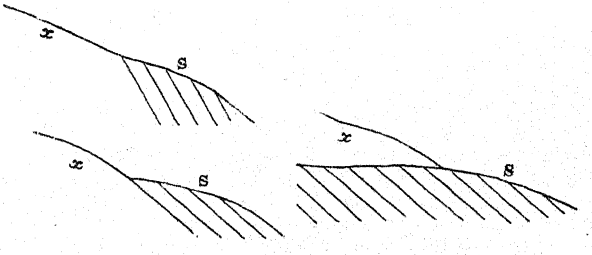
In fig. 2, the portion *x* may be found either to overlie or to underlie the stratified beds when sufficiently opened to show the connection.

Fig. 3.



In fig. 3, though *x* overlies the stratified beds, it may be found either conformable or unconformable to them.

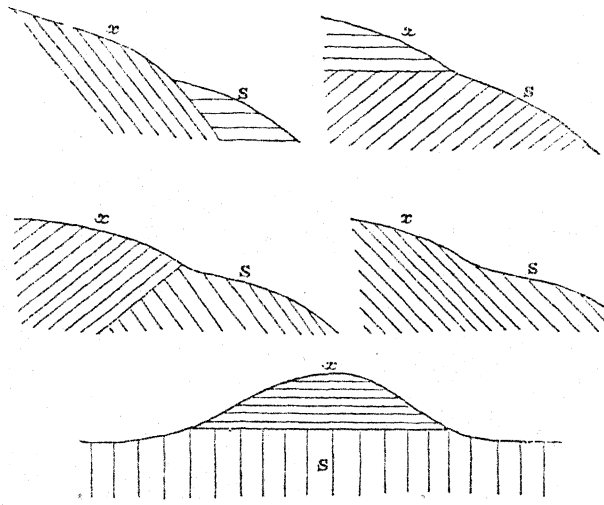
Fig. 4.



In fig. 4, *x* may either underlie or overlie the stratified beds.

x has in these cases been represented as itself unstratified; it may, however, be also stratified, and then the following example will show the possible results.

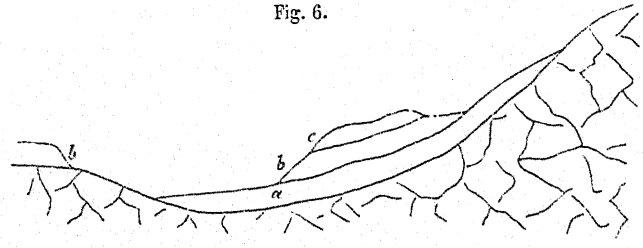
Fig. 5.



In all of which, *x* is unconformable to S, excepting in the fourth, where it is conformable to S, although possibly of a different mineral character.

It will be observed from these examples how much caution is required in determining the exact conditions of stratification, and in not too hastily deciding that a rock is older or younger than another from its *apparent* position; and further this is shown more distinctly in

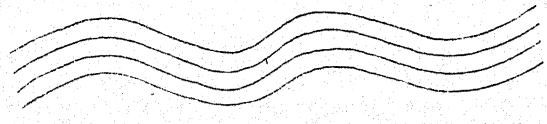
Fig. 6.



where *a*, though generally lower in natural position, as it is older in geological age than *b*, rises up from below it to a higher level; and again *b*, though underlaid by *a* at one point, rests itself directly on the massive rock at another, and might be, even from a mere comparison of levels, supposed to underlie the elevated portion of *a*.

Strata are frequently undulating on the large scale, though, when examined at any one point, they may appear to have a uniform inclination.

Fig. 7.



This arrangement may be due either to original depositions on a previously modi-

fied surface, or to gentle movements of the underlying mass prior to the consolidation of the overlying strata. The crest or ridge-line transverse at its highest point to each bend, as here shown in section, forms an anticlinal ridge either in the direction of the line of strike, or nearly so; and a line carried in a similar direction along the hollow between two bends is the synclinal line.

FLEXURES AND CONTORTIONS OF STRATA.

The case of gentle undulations above noted is simple, but the flexures and contortions of strata are often exhibited on a grand scale, and with appearances of the most striking kind. See Plate II. figs. 7, 8; Plate III. fig. 16.

To illustrate such flexures and contortions of strata, an experiment was made by Sir James Hall. Several layers of clay were placed under a weight, and their opposite ends having been pressed by considerable force more closely together, it was found on the removal of the weight that the layers were curved and folded so as to resemble, in miniature, the natural strata. Other similar illustrations have been proposed, the materials acted upon in all of them being supposed flexible; the crystalline schists, however, in which contortions are so frequent, are of such great hardness that they could not have been forced into such forms without having been shattered, or at least cracked at the bends. That such internal movements have often taken place, even in highly indurated strata, cannot be doubted; and that one bed has sometimes been forced over another and the surfaces of both broken up and formed into a breccia, seems evident from the brecciated structure of some strata; but in the present case it is more probable that these now highly indurated and crystalline strata were, at one period, soft and pliable. This statement may be illustrated not merely by examples drawn from the more ancient gneiss, mica slate, etc., but also from the contortions in rocks of which the sedimentary character cannot be doubted, although they have subsequently assumed a high state of induration.

In the Carpathian chain, the metamorphic rocks, including gneiss, mica schist, talc schist, clay slate, associated with syenite and porphyry, are succeeded by an extensive formation of sandstone. Intercalated with this rock, in several places, are beds of limestone, which, from their fossils (ammonites, etc.), have been allotted either to the green-sand, the whole formation therefore belonging to the cretaceous system, or to a connecting link between the oolite and the chalk. In either case it is a formation comparatively recent, and as it comprises clays and limestones with the sandstone, it is very favourable for studying the mechanical effects of pressure, as well as those of metamorphism. For example, it is stated that the schistose clays have in some places become silicious slates, with occasional veins of cinnabar, the marls have been converted into jasperoid rocks, and the sandstones either into quartz rock or into highly quartzose grit full of pyrites, whilst the mechanical changes during this metamorphic action have been equally striking, as exhibited in Plate II. figs. 7, 8. The first example is from a locality where the Carpathian sandstone, there associated with thin beds of limestone, exhibits the singular flexures represented; the second, from one where the sandstone is beautifully contorted; and many similar examples might be cited from the memoir of the late M. Lill, on the Carpathian Mountains ('Mémoires de la Société Géologique de la France,' tom. i.).

To these I have added (Plate II. fig. 9) an example from the marls of the new red sandstone of the county of Derry, in which the alternating beds of hard calcareous grit exhibit some very curious contortions; and another (Plate II. fig. 10) from Lyell, taken from tertiary beds in Sicily, where thin beds of solid gypsum are interstratified with bent and undulating gypseous marls, the solid beds having been broken into de-

tached fragments, still preserving their sharp edges, while the continuity of the more pliable and ductile marls has not been interrupted.

In endeavouring to explain such phenomena, it is desirable not to lay too great a stress on any one cause of change to the exclusion of others: there can, for instance, be no doubt that many minor contortions, and some flexures in strata, may have been the result of original deposition on banks and amidst the eddies of currents; but we cannot ascribe such flexures as those described by Lyell, who states that "curves of calcareous shale are seen from 1000 to 1500 feet in height, in which the beds sometimes plunge down vertically for a depth of 1000 feet and more, before they bend round again," to such a cause, and must look upon them as striking evidences of disturbance. In respect to the Carpathians, M. Boué states that the mountains of Hungary and Transylvania indicate upheaving, accompanied by fractures in four directions, viz. from S.W. to N.E., from N.W. to S.E., from W.S.W. to E.N.E., from S.S.W. to N.N.E., and fractures without upheavings, or faults, generally from N. to S. or from E. to W. Of these directions, the first two, S.W. to N.E. and N.W. to S.E., are common to the crystalline schists and to the secondary rocks, showing that movements had taken place affecting both these classes of rocks; whereas the directions from W.S.W. to E.N.E., and from S.S.W. to N.N.E., affect the schists alone, and were therefore antecedent to the formation of the overlying secondary rocks of the country. A similar result may be observed in the mica schist district of the North of Ireland, where the prevailing strike of the schistose strata is from W.S.W. to E.N.E., whilst the secondary sandstones rest undisturbed upon their edges. (See Plate III. figs. 11, 12, 18.) M. Boué also observes, that in the Carpathians, from the absence of the lower secondary strata, the actual age of the crystalline schists cannot be determined, though they are manifestly older than a portion of the secondaries; the epoch of disturbance being probably anterior to the oolitic period, if not to that of the new red sandstone, and the chains of Western Hungary, the prolongation only of the Alps and the Jura, or oolitic strata, as well as of a portion of the red sandstone, which overlie unconformably the more ancient Alpine strata.

The upheaving in a direction from S.E. to N.W., and in that from S.W. to N.E., has given rise to numerous contortions in the Carpathian strata, extending even to the beds of molasse deposited at their base; so that this movement or disturbance must be at least posterior to the tertiary strata, of which that deposit is a part. In a similar manner M. Boué traces the probable *geological* dates of the other lines of disturbance, and shows their probable connection with the appearance (eruption in his opinion) of certain igneous rocks; namely, of syenites in the secondary period, of metalliferous porphyry in the lower tertiary, and of trachyte in the upper tertiary.

CLEAVAGE.

In studying stratification, or the successive deposition of strata, a difficulty is often experienced in the appearance of other lines of division, which are called cleavage. When rocks contain fossils, beds of flints, or layers of pebbles, and in alternating strata of very different composition, such as sandstone, limestone, or shale, this difficulty can generally be removed; but in cases where the deposit is uniform for a great thickness, or consists of massive beds, it is necessary to use considerable caution in deciding which is the true plane of stratification.

Stratification, then, is the result of successive deposition; and though its planes are often irregular or undulating on their surface, and comparatively uninterrupted, they possess a considerable lateral extension. Cleavage, on the contrary, is induced by forces acting subsequently to deposition, and its planes exhibit surfaces more even

but more frequently interrupted, as they pass through, or intersect, the planes of stratification; and a little attention to this distinction will often enable the observer to decide which is a plane of stratification, and which is one of cleavage.

A smaller description of cleavage, which has probably resulted from the arrangement of minute plates of mica in definite planes, during the deposition of strata, as suggested by Mr. Sorby, is very remarkable in slates, which are frequently fissile in directions not parallel but transverse to the stratification; but it may also be observed in sandstones, and also in the more recent detritic (diluvial) deposits. See for the first, Plate III. fig. 13; and Plate III. fig. 14 for the other cases. The very excellent observations of Mr. Sharpe, who has followed out the researches of Sedgwick, Phillips, and Darwin, on the effects produced on fossils by the expansion or disturbance of the strata, and their relation to the planes of cleavage, prove the general connection of cleavage with the great elevating forces; and Professor Tyndale has shown by experiment, that pressure of any kind produces on the material masses to which it is applied, a tendency to cleave in a direction perpendicular to that pressure, so that the cleavage planes become an evidence of the direction of the disturbing force which has produced them.

Foliation.—The splitting or scaling of a rock in thin irregular laminæ may be due either to stratification or to cleavage; and the term therefore ought to be used mineralogically rather than geologically.

Joints.—Joints are the cracks which are produced by the gradual contraction in a mass during consolidation.

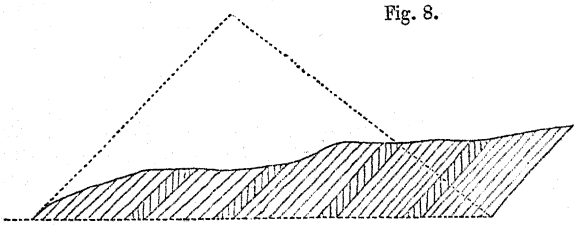
DENUDATION AND WEAR.

The term denudation, though strictly meaning the act of laying bare, is geologically applied to the result of that operation; so that a valley is said to be a valley of denudation when it has been produced by the removal of a large mass of superincumbent strata, and the consequent denudation of the underlying rock. Though in reality this is only one form of the general problem of wear, it deserves especial attention, as proving the vast operations of the most simple natural causes, and to connect together their workings at the most distant epochs. If it were asked what has been the amount of denudation, the reply should be, with Lyell, that it may be measured by the whole mass of our stratified deposits, as they have all been detached and removed from their primeval positions. If the question were, "At what time did it commence, and how often has it been repeated?"—that its commencement must at least have been anterior to the deposition of the crystalline schists of the earliest epoch, and that it has been repeated during every successive epoch of the earth's history. Such considerations as these will enable the observer to form a just estimate of the magnitude of the phenomena before him, and warn him not to deny their possibility because unable to realize the forces which produced them. In no other science indeed is the power of philosophic generalization so important as in Geology, where the observer is constantly called upon to admit in his mind the working of some very simple cause with some grand result, which at first sight may have appeared quite unconnected with it.

In considering the denudation or wear of the crystalline schists, we meet the solution of a difficulty which led even Playfair into error. That profound philosopher, in discussing the probable thickness of the known portion of the earth's crust, assumed the apparent succession of outcropping strata as a sufficient indication of it. For example, in a mica schist district an unbroken series of strata may be traced, dipping at an angle of 30° or 35° for probably 50 or 60 miles; and if it were assumed, as by Playfair, that all these beds were originally deposited one upon the other in a

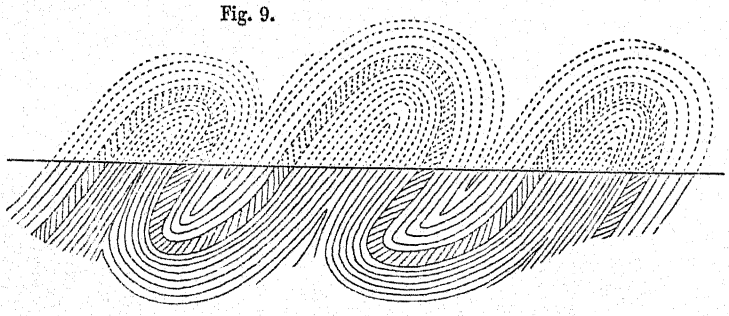
horizontal position, and subsequently elevated by a disturbing force, we should be able to deduce from them a very considerable thickness. In No. 8 we suppose a

Fig. 8.



section of the strata visible for 30 miles, in which the dip is 30°; and if they had been originally horizontal, the total thickness would be 30 sin. 30°, or 15 miles, and consequently the edge of each stratum must have been raised that height above the horizontal plane. Had the dip been 45°, a very usual one in the crystalline schists, the thickness would have been 21 miles, and the rise of the stratum edge the same. That the dip of strata is often partly due to original deposition on banks is undoubted, but there can also be little doubt that in this description of strata it is principally due to subsequent disturbance, which is strongly supported by the frequency of contorted strata in all districts of gneiss or mica schist. Whoever has carefully examined such districts, must have been struck by the repeated alternations of certain sets of strata, such as quartz slate, thick beds of quartz with micaceous specks, granitiform gneiss, mica schist passing into gneiss, mica schist passing into clay slate, layers and beds of granular limestone, &c.; which, if all considered independent beds, would imply an extraordinary amount of deposition, and a multitude of variations in the forces producing it, without any great disturbance, followed by the exhibition of some great and controlling force capable of modifying the whole mass through a thickness of 30 miles, disturbing and elevating it at the same time; whereas the application of the theory of lateral pressure, which corresponds to the undulating movement of the earthquake, explains the phenomenon in a more simple way, as it represents these alternations to be the foldings of the strata in contortions, many of which are still visible, whilst others have been truncated by denudation, in the manner shown in No. 9, the surface having been further modified, by subsequent wear and the removal of the softer strata, into mountain and valley.

Fig. 9.



Contorted Strata, removed, above the line, by denudation.

To render both classes of inclined and undulating strata as clear as possible, a section of the strata of the district of Vassy, in France, by M. Cornuel (Mém. Soc.

Géol. tom. iv.), is given in Plate III. fig. 15, in which undulating beds, rich in iron ore, are seen to dip into the hollows previously worn in a portion of the oolitic strata, the dips in the iron beds having been subsequently filled with ferruginous sand. The whole of these beds are supposed by M. Cornuel to be anterior to the chalk, and they afford a very interesting example of denudation at that epoch. The form of undulating beds seems also to have prevailed during the carboniferous period, and the dipping strata have sometimes been so perfectly truncated by denudation, as to exhibit on the surface of the soil a horizontal plane. In the shales also of this formation occur examples of wear, prior to the deposition of the overlying beds, so striking, as almost to point out the direction of the denuding currents.

In Plate III. fig. 16 is a portion of a section by Dr. Lusser, of the Alps, from St. Gothard to Asti on the Zugersee, in which the author marks out by dotted lines the supposed original continuity of the strata, the contortions of which are exhibited on a magnificent scale. These strata, although greatly changed by metamorphic action, are, in the author's opinion, continuous with those containing nummulites, and therefore not older than the upper secondary or lower tertiary: they are, as usual, in immediate connection with the crystalline schists, especially with gneiss. In Plate III. fig. 17, an example is given of the deep denudation of the ordinary stratified deposits by currents or streams, unaccompanied by any great movement of disturbance. In Plate III. fig. 18, mica schist is covered unconformably by new red sandstone, which has been disturbed after deposition. In fig. 12 the strata are shown unconformably to the schists below; whilst in fig. 11 the schists are quite denuded.

These examples are sufficient to enable the observer to appreciate the vast amount of denudation. It has gone on at all periods, and wherever one formation is laid bare by the removal of the overlying strata, evidences of its previous wear may be discovered, and that even in parts of the same formation; as, for example, a tertiary sandstone at Corfu has been exposed to considerable wear prior to the deposition of overlying blue clay, as is shown by the partial removal of the latter at the brick establishment of the Engineer Department at San Pantaleone, and the exposure of the worn surface of the sandstone below it.

FAULTS.

The preceding phenomena have implied lateral movements and pressure, accompanied or followed by extensive denudation or wear. The present are the result of vertical movements, by which whole masses of strata, having been dislocated, have either slid down or been forced up, the same strata appearing thus repeated at a higher or lower level. See Plate IV. figs. 19, 20, 25; fig. 25 being a curious example, in which long tuberous-like deposits of iron ore have with the strata been affected by a fault. In this case, then, the retaining force is lateral, and the moving force vertical, though probably sometimes also a resultant of lateral pressure; and it is also highly probable, from the frequency of faults in all shale districts, that one cause of their occurrence is the shrinking of the mass, and another similar to water and land slips. Fig. 20 is an example of faults in a coal mine, in which their great importance, as well as the trouble they sometimes occasion the miner, are well known, and will again be noticed in the more practical part of this essay. See also Plate VI. fig. 34.

Although in itself great and striking, the actual amount of the vertical disturbance, as exhibited in faults, is small compared with the lateral, as displayed in contortions. In the Newcastle coal district, the upward or downward movement has amounted to nearly 1000 feet, so that the surface must have been originally affected to that ex-

tent, portions have either risen or sunk 1000 feet above or below the rest, although the projections or inequalities consequent on such movements have been subsequently removed by denudation; the faults being only discovered by studying the internal structure of the underlying strata. On every side, then, and at every level, whether we look at the varied surface of our earth as it now exists, and as it is now exposed to the incessant wear of rains, of torrents, of rivers, and of seas,—or seek for information within the deep recesses of the excavated mine, we find the same tale narrated, of continued disturbance and wear on the one hand, and of renewed formation on the other.

ANALOGY OF MODERN AND ANCIENT SEA CLIFFS, SEA BEACHES, GLACIERS, AND ICEBERGS.

So long as the worn materials of the earth's original crust, deposited in rocky beds, afford no evidence of the existence of air-breathing animals or of plants, traces of atmospheric action, which depends on a partial exposure of the surface above the level of the sea, ought not to be expected. The vast beds of sandstone and conglomerate, which prevail at certain geological epochs, indicate extensive wear and equally extensive deposition, of which the type should be sought in the accumulations of sand and gravel which now constitute submarine banks. The extent of known sea banks is sufficient to support and confirm such a reference; for example, of the banks of Newfoundland and the Bahama bank: and when it is considered that soundings of only moderate depth are obtained on these banks in the midst of the ocean, they may be fairly considered as analogous to and commensurate with any of the ancient banks which are now beds of conglomerate or sandstone. In a similar manner, as ancient conglomerates were formed by gradual accumulation of beds of sand and gravel, so are our modern banks, now forming by the action of marine currents and of the floating fields and bergs of ice, which convey with them the detritus of one region and deposit them in another. In the hydrographic instructions issued to Captain Beechey by the Admiralty, prior to the voyage of the *Sulphur*, it was enjoined that the deep-sea lead should be cast at convenient periods, even where no shoal was either known or suspected to exist; and such a rule, followed by all Her Majesty's ships of war, must produce much valuable information, to be used as data for determining the progress and changes of such deposits. Every time the lead touches the bottom, a point of comparison is obtained, and a datum for future investigation secured; and when a shoal is first discovered, preceding voyagers ought not always to be blamed, as it is at least probable that in their time it had not been raised within the reach of ordinary soundings. If it were in our power to examine the internal constitution of sea banks, the occurrence here and there of the trunk of a water-logged tree, or of the hard fruits of plants, might be expected; but if we found beds of lignite or fossil wood, we should be obliged to assume that the bank had either been exposed to the air, and had supported a growth of air-breathing plants, or at least had been formed in some shallow ancient estuary, adjacent to rivers with banks clothed with trees: in a similar manner, the occurrence of fragments of anthracite in ancient rocks, shows that some portion of the earth at the time of their formation may have supported a growth of plants, but not that they also had been exposed; whilst the existence of beds, either of lignite or of coal, in a formation, proves that its strata had either been covered with plants or were contiguous to other parts of the earth then covered with them. Such evidence does exist both in the ancient coal beds of the carboniferous and other strata, and in the lignites of the still more recent tertiaries; and it proves that at a very remote geological epoch, some portion of the earth's surface had already emerged from be-

neath the water, and been exposed to wear from the surges of the ocean beating on the shore, giving rise then as now to sea cliffs and gravelly or sandy beaches.

It is not always easy to trace the cliffs or sea boundaries of these ancient periods, as most of the strata have again been submerged and covered by more recent strata; but the ancient sea bottom has often been laid bare, as at Lough Erne, in Ireland, where may be seen on the shore a limestone covered with projecting corals, now exposed by the removal, from denudation, of the shale above it.* Whoever, indeed, has noticed the manner in which the sea bottom in a warm climate is thus covered over by corallines (for example that of the Mediterranean), will perceive the force of this analogy. Shore wear may be doubtless noticed at every geological epoch; but after that of the deposition and consolidation of the chalk, it is more apparent. Mr. Lyell gives several examples of inland chalk cliffs which occur in Normandy, but none can be more striking than the curved escarpment of chalk which bounds the plain of Dungiven, in Derry, the tertiary clays with their marine shells occurring below it, and demonstrating in the most striking manner the existence of a former sea bed at levels now 200 feet above the present sea, though the sea cliff was then, as now, chalk.

Plate IV.—Fig. 23 exhibits an example of this peculiar evidence of geological analogy; and fig. 24 another equally striking, namely, the occurrence of successive ancient sea beaches at elevations far above the present sea-level. The wear of the ancient and now inland cliffs, of the chalk, as also that of the white limestone of the Morea and of Sicily, took place during the deposition of the beds subsequent in date and now called tertiary, and it has often produced a succession of cliffs at different levels, corresponding to so many successive pauses in the elevating forces; the base of the ancient cliff being sometimes occupied by an ancient mud bank, and at others, by a former sea beach. Our subject may here be so far anticipated as to state, that in the strata called tertiary, the first decided† approximation to the existing order of things may be noticed in the occurrence of the remains of organic beings identical with those still living in our seas, as also in the similarity of the erupted basaltic and trachytic lavas of that period with those of existing volcanoes. We seem, indeed, when studying them to be entering on the history of the earth as it now is; and as we advance further into the light of recent day, new evidences of continued change are met with in the occurrence of sea beaches of still more modern date, although now far removed from the present action of the sea. Mr. Smith, of Jordan Hill, an indefatigable observer of this class of geological phenomena, has, for example, pointed out the existence of ancient sea beaches in Gibraltar, as also in Scotland and in Ireland, in which country Mr. Bryce and myself had also pointed out examples of the temporary rest of the ocean at points of the earth's surface, in the North of Ireland, now far removed from its action; and still more, much valuable information of the same kind has been afforded by our brother Officer Lieutenant-colonel James, who examined the gravel beds of the South of Ireland, and his inquiries have been subsequently extended and perfected by the Government Geological Survey, now under the direction of Sir Roderick Murchison.

In the cave of Uddevalla, in Sweden, this change of level was long since proved by the existence of cirrhipeda adhering to its walls, just as they are now found attached to the rocks of the sea-shore; so that both by the evidence of mechanical

* See Plate IV. figs. 21 and 22, for an illustration of this curious phenomenon, taken from 'Observations Géologiques sur le Jura Soleurois,' per A. Gressly.

† The term 'decided' is used, as Professor E. Forbes has shown that there is reason to believe that at least one annelid is common to the chalk and to the exisiting epoch. Nummulites are common to the chalk and tertiary, so that this fact would connect more closely the chalk and tertiary deposits, by carrying into the former an existing type of organic life.

wear and of organic relics, we are carried back, step by step, to ages beyond the reach of historic records. And when the organic links of identity are lost, we can still trace by mechanical effects the working of similar causes up to the remotest epoch,—an epoch so remote, that Mr. Lyell has estimated even a small fraction of the time evolved, namely, that during which the comparatively recent deposits of the Mississippi have been formed, and the wear of its valley effected, at many thousand years. Another example of wear may be quoted in the present condition of Portland Island, cut off from the mainland by the undermining of its more solid strata, and the removal of an underlying stratum of clay. At present, the Chesil Bank, an accumulation of sand and gravel, forms a natural breakwater, and lessens, though it does not stop, the progress of wear; but should another slight elevation bring up the clay nearer to the water's edge, the wear would advance again with rapidity, and the island once removed, the Chesil Bank itself would speedily be destroyed, and the sea would advance upon the mainland. The consideration of this case is of much practical value. The wear of Portland Island is comparatively diminished, because the dip of the beds is such as to carry the subjacent clay to a depth beyond the action of the moving wave, and to reduce the wear to that of the more solid rock: the Chesil Bank has been formed because the remaining portion of solid rock projecting forward checks the force of the current, and causes the deposition of the pebbles moving with it. The pebbles of the bank protect the subjacent clay from further wear, and thus the general tendency is, to preserve a tottering equilibrium, which the slightest change will destroy. In this case a renewal of elevation would lead to renewed destruction, whereas, when elevation brings up a solid stratum, it stops destruction; and such must have been the varying results of elevation, as also of depression, at all geological epochs. In examining any coast, therefore, with a view to judge of its probable permanency, the following particulars should be especially noticed: 1st, the nature of the shingle or gravel, as showing the direction of prevailing currents; 2ndly, the prevailing and most powerful winds; 3rdly, position and character of any barrier sheltering from the prevailing winds; 4thly, position and character of any barrier opposed to the prevailing current; and further, that in protecting a coast, the accumulation of shingle should be effected by a barrier transverse to the line of current, bearing in mind that the movement of the shingle is by a succession of steps, obliquely upwards by the force of the impelling wave, and nearly perpendicularly downwards by the force of gravity. To bring the processes of wear and formation to an equilibrium, it is necessary to keep the forces producing them in a similar ratio to each other, as the alteration of any one must lead to a change in the others. At present, for example, the Isle of Wight forms a barrier of protection to much of the opposite mainland; and everything which tends to preserve its outline unchanged, has an equal tendency to keep the wear of the opposite shore within assignable limits.

Similar vestiges of ancient river as well as lake wear may also be cited: of the former, an example is given, Plate VI. fig. 30, in which the former bed of the river Burnthollet, in the county of Derry, appears to have been 10 feet higher than its present course, as shown by the remarkable masses of rock still remaining to attest its ancient wear: of the latter, the parallel roads of Glenroy, so often quoted, may be again cited here. These roads are ancient shelves or beaches, formed at the margin of a former lake, and at levels corresponding to its successive depressions. The highest is 1250 feet above the sea, the next about 1000, and the third 50 feet lower. Mr. Lyell remarks, that "Among other proofs that the parallel roads have really been formed along the margin of a sheet of water, it may be mentioned, that wherever an isolated hill rises in the middle of the glen above the level of any particular shelf, a

corresponding shelf is seen at the same level, passing round the hill, as would have happened if it had once formed an island in a lake" (Plate VI. fig. 31); and the great lakes of America exhibit similar lake beaches at various elevations above their present surface.

In addition to these forms of gravel deposits, Agassiz has brought prominently forward the banks or 'moraines' of ancient glaciers. It had been long known that the vast accumulations of snow which produce the glaciers in Alpine valleys, were from the higher valleys, where they are formed, to the lower, where they are gradually melted; the portion cut off or melted at the lower end being replaced by a new mass added at the upper end, and the fact is now considered undeniable. In moving along, the glacier carries with it the fragments of rock which, having fallen from the precipices above, have formed upon it lines of deposit, to which the name of 'moraine' has been given; of these M. Agassiz distinguishes three varieties,—lateral, in which the moraine borders the valley of the glacier, resting either partly on its surface, or between it and the side of the valley;—medial, in which the moraine is formed of a long line of débris stretching down the course of the valley like a ribbon on the surface of the glacier;—terminal, in which the moraine is at the lower or terminal end of the glacier; and these forms of gravel deposit, interesting as regards the history of the glacier itself, become still more so when used as a clue to the explanation of gravel deposits now now no longer connected with glaciers.

It will be readily admitted that any considerable variation in the temperature of the air must produce a similar variation in the amount of snow and ice, and either an augmentation or a diminution in the resulting glaciers. Within very recent times, the change has been in the direction of cold, as shown by the inquiries of Mr. Venetz on the variations of temperature in the Swiss Alps; but if more ancient epochs are taken into account, the evidence shows a rise of temperature.

M. Venetz establishes the first of these positions by historical monuments and documents, which prove that some of the Alpine-passes, now scarcely practicable, were once the ordinary lines of communication; and in the archives of the Commune de Bagnes, M. Rivaz noticed a legal process between that commune and the commune of Liddes, relative to the possession of a forest then on the territory of Bagnes, which has since disappeared and been replaced by a glacier, now entirely cutting off the communication.

Many other examples might be cited of the extension of the glaciers within the last 200 years; but how small it appears when compared with the vast extension in times beyond the reach of historical evidence, for, as M. Agassiz observes,—"We shall be forced to admit that many moraines, far distant from existing glaciers, must have been formed at the most remote periods, if not anterior to the creation of man." The careful examination of deposits classed by him with moraines, has enabled M. Agassiz to trace, assisted by other phenomena, the action of glaciers in countries now far removed, by their comparatively elevated temperature, from the sphere of their production, and having thus brought the British Islands within the sphere of ancient glacial action, his inquiries have been successfully followed up by Dr. Buckland and many other British geologists.

Such inquiries have led to the belief that there was a period of intense cold, when ice and snow were spread over a large portion of the northern hemisphere; when on the coasts of that frozen epoch, the glacier descended, as it now does in Spitzbergen, to the sea, when icebergs were formed, and the open sea was covered with them and with floating sheet-ice. Glaciers were the carriers on land of those fragments which formed ancient moraines;—icebergs and floes were the carriers on sea of those vast fragments which now as 'erratics' are dotted here and there along the course of

former marine currents, just as the modern floe or iceberg leaves at the bottom of the ocean, when it grounds and melts, the fragments of rocks it has carried along with it. Perhaps no one now admits the operation of glaciers, in the extended sense of Agassiz; though the careful examination of recent phenomena has in this, as in many other cases, supplied the means of appreciating the nature and magnitude of the operations of nature at the remotest epochs.

PETRIFACTION.—ORGANIC REMAINS.

In the preceding sections, allusion has occasionally been made to fossils, or the remains of organic beings, found in the ancient strata of the earth; and it is now time to explain the manner in which such relics have been used in studying the past history of the earth. In this, as in every geological inquiry, such definite data as the present course of natural events affords us should be adopted as the framework and theory, and not, as was the custom with ancient geognists, a speculative opinion formed first, and data to support it looked for afterwards. In investigating, therefore, the laws of ancient organisms, it is necessary to study the laws of life now in operation; Professor Edward Forbes has, for example, shown that the influences of climate upon land animals and vegetables, are in marine animals much modified by depth of water; and that it is necessary to take into account this condition, in comparing either existing marine animals at different and distant regions, or extinct animals of former epochs. On this most important view of the subject, M. A. Gressly has also published, in his 'Geological Observations on the Jura' (1837), some interesting remarks, an abstract of which will best explain the principles he advocates.

On a careful examination of any deposit, various modifications may be observed, in the petrographic constitution of the strata corresponding to others, in the palæontological character of the fossils, and which are subject to peculiar and little varying laws. Two principles are deduced from these considerations.

1st. That a peculiar petrographic constitution in a stratum will be accompanied by a peculiar palæontological assemblage of fossils.

2nd. That such a palæontological assemblage will not include the genera and species peculiar to strata of a different petrographic constitution.

If certain genera and species peculiar to one form of mineral stratum be found in another, the individuals of such genera and species will be much more rare, much less developed and less distinctly characterized, than in that to which they properly belong. And further, it may be assumed, that where the petrographic characters of a stratum are the best developed, so also are the fossils better preserved, most fully developed, and best characterized; and on the other hand, where the petrographic characters appear uncertain, so also are the fossils obscure, rare, imperfectly developed, and badly preserved.

The modifications, petrographic and palæontological, which a stratum exhibits in its horizontal extension, depend on those variations in position and circumstances which so powerfully influence the arrangement of the genera and species now living in our existing ocean; or, in other words, the distribution of fossils, and the corresponding petrographic and geognostic conditions, prove that the laws of organic association and the conditions of existence in the submarine world have been the same in all ages.

In this manner a deposit may have been a shore deposit, an ordinary shallow sea deposit, or a deep sea deposit; and in each case a peculiar combination of organic bodies should combine with its petrographic constitution to characterize it. In applying these principles to the rocks of the Jura, M. Gressly ascribes to them two distinct forms of origin,—

a. A purely mechanical one, in which they were formed in the midst of an agitated sea; as, for example, rocks of a brecciated or rudely oolitic character.

b. An origin, partly chemical, in a quiet sea; as for example, marls, marly and compact limestones, either with a homogeneous paste, or with a paste finely oolitic, in which the grains are, as it were, fused into the paste.

These two types, variously modified according to their littoral or pelagic station, lead to distinct stratigraphic forms, and are accompanied by equally distinct and characteristic palæontological combinations. Rocks, for example, of a brecciated or of a rudely oolitic character, constitute the coralline type. They indicate a littoral or shallow-water deposit, the fossils being those of coral banks, principally fixed corals, with a massive or blanched stem capable of resisting the shock of the waves, and corresponding to the living genera agaricia, astrea, oculina, caryophylla, etc., which now form in intertropical seas the coral banks and reefs so dangerous to ships, accompanied by other organic bodies which usually inhabit coral reefs, and appear to delight in continually agitated waters, some being firmly attached to the rocks, and others possessing a highly elastic structure, which, yielding at once to the impulse of the wave, brings back the animal unhurt to its former position, when the shock has passed away. Amongst these are the crinoids, with their long, elastic and flexible stems,—the more solid echinoderms, with either globular or flattened shells and strong plates and spines, such as the genera cidaris, diadema, and clypeaster,—whilst the spatangi, with thin shells and delicate spines, are much more rare. Amongst the mollusca, whether acephala or gasteropoda, those genera abound which, like the oyster and spondylus, have firm bases of attachment; or, like the perforating genera arca, saxicava, venerupis, can remove themselves by self-formed cavities from injury; or, like the genera trichites, chama, perna, are made secure by the weight of their shells; or, like the pecten, lima, and terebratula, are preserved by the elasticity either of their shell or of their ligament of attachment; or, as in the genera turbo, trochus, nerina, patella, etc., by the solidity of their shell or by adhesion to the rocks; it may indeed be assumed, as a very important and almost universal character in organisms of the coralline type, that their shells or crusts were massive, and marked by ribs, striæ, spines, knobs, and other peculiarities, which, whilst strengthening them for opposing the contingencies of their peculiar location, now serve as so many valuable characters for studying them as inhabitants of an ocean long since passed away.

Deposits which may be called shingle, and were the result of the active wear of the waves, are often intimately connected with coral banks, but also accompany and link together all the petrographic forms of deposit. They possess few zoological peculiarities, borrowing, as it were, the characters of the several deposits with which they are connected by receiving from them the fragments of their various organisms. Muddy deposits, such as marls, compact and sub-compact limestones, together with sands and sandstones, constitute another important class, and exhibit a totally different zoological assemblage. The corals are of spongy and incrusting genera, and generally without apparent base. Crinoids are rare, scattered about, and generally of unattached genera. The echinida are less rare, particularly the true echini and their congeners, though the spatangi abound in muddy and sub-sandy deposits. Of the asterida, the genera asterias and saccocoma are characteristic of muddy deposits and of fine sands and gravel. Of the acephalous mollusca, the genera which abound are—solen, pholadomya, myopsis, pinna, tellina, mytilus, modiolus, corbula, isocardium, cucullea; and amongst the ostracea especially—gryphea and exogyra. In the gasteropoda may be noted—rostellaria, pterocera, natica, turritella, fasciolaria; and amongst the cephalopoda—the genera nautilus, ammonites, belemnites. Fish with pavement-like teeth are very characteristic of these mud deposits, and reptiles are

abundant, though locally distributed, in the upper Jurassic beds, more especially in what may be deemed muddy shore deposits. A nearly constant character of all zoological assemblages in muddy deposits, is that the prevailing genera and species are provided with smooth and thin shells, or coverings not fitted to withstand the wear of transport; and in those genera which possess a thick shell, the tissue is nearly non-elastic, and easily disintegrates. On muddy bottoms also the genera were more frequently free than attached, the stems of pentacrini even appearing to have been fixed by fibrillæ or simply immersed at their base in the mud.

The sub-pelagic and pelagic forms of muddy deposits, though corresponding to the littoral form in their petrographic conditions, are distinguished from it by zoological peculiarities. The deep sea or pelagic deposits are very uniformly constituted, homogeneous, regularly stratified in continuous and often massive beds, except where modified by disturbing forces. In these deposits, large spaces are often deficient in organic bodies, or contain only their débris, together with those spongy and fibrous corals which are supposed to inhabit the waters of great depths. M. Gressly sums up in these important deductions:—

1. Each class or form of deposit presents characters—petrographic, geognostic, and zoological—peculiar to itself, and distinct from those of any other class or form of deposit, although of the same geological epoch.

2. That the same class or form of deposit, as regards its petrographic and geognostic condition, exhibits very analogous zoological characters in each successive geological formation in which it occurs.

These laws are of great interest, and highly important in the application of zoological characters to the determining of geological formations; though care must be taken not to include in the truly characteristic fossils those which have been brought by currents from other formations. In the muddy sub-pelagic bottom of the channel of Corfu, in the Ionian Islands, many of the thin-crusted and silky-spined spatangidæ are found, together with nuculæ, tellinæ, corbulæ, and other organisms fitted for such a habitus; but these are combined with abundant exuviæ of other organisms foreign to such a habitus,—as the valves of strongly-ribbed cardia, pectens, &c. In the one case, the shells, &c., are generally perfect or alive; in the other, more frequently separated and injured; the bivalves, when connected, being often wide open or even twisted round; and the geologist will recognize similar cases in the deposits of ancient worlds, as, for example, in the Devonian fossils, described by Mr. Phillips in his work on Palæozoic Fossils, which are singularly broken and defaced; and this consideration leads to the establishment of the following additional rule:—

3. In every petrographic class of deposit, two sets of organisms may be expected to occur; the one suited to the habitus which its geognostic position indicates, and which is therefore its truly characteristic organisms, or those which should be used in any comparisons between it and a similar deposit occurring again in the same or in any other formation; the other, extraneous organisms, the absence of which in the same class of deposit at some other locality, would not be evidence of a geological difference, but simply of freedom from modifying influences.

This method of referring the conditions of zoological existence at ancient epochs to those of the present, was exemplified by M. Gressly in such cases as the abrupt terminations of peculiar petrographic deposits, the local distribution of fossils, &c., which are still repeated in nature, wherever a mud or other bank is cut off by a current, or where a local deposit is formed under the lee of projecting rocks, or the shelter of a coral-reef; but it would be useless to go further, as enough has been said to guide the observer to a right mode of geological inquiry in tracing out any particular formation in its lateral extension. When the inquiry is made in a vertical direction, or by the aid of natural and artificial sections, the same classes of deposit

are observed recurring at different intervals, and exhibiting a similar analogy in the assemblage of organisms connected with them; but this analogy, the result of similar conditions of existence, is not identity, which would require that all the organisms of the two periods should be specifically the same, and this difference leads to the following rule:—

4. Similar variations in the conditions of organic existence must produce similar modifications in the assemblage of organic beings existing at the same epoch in the various places subjected to such variations; such modifications however taking place in the assemblage, and not, except in a very slight degree, in the individuals themselves. Want of identity therefore in the organisms of the same petrographic class of deposit, as seen to recur in a section of any part of the earth's crust, cannot be explained by a variation of the conditions of existence, the petrographic and geognostic *identity*, combined with the zoological *analogy*, showing that the conditions were the same, but must be ascribed to a difference in the aggregate fauna and flora of the epoch; or, in other words, it proves that the organisms of the strata, compared together, were connected with two distinct periods in the earth's history.

If the mode of petrifaction be now examined, the identity of past and existing agencies will receive further confirmation.

The relics of ancient worlds discovered in the mineral strata of the earth may, from their forms, be classed either in the vegetable or animal kingdoms. The first observers of these remarkable bodies did not overlook their resemblance to still existing organisms; but, either unable to account for their composition or situation, considered them as 'lusi' proceeding from the exercise of a plastic power in nature, or, admitting them to be the relics of organized bodies, yet not perceiving the specific distinction between them and still existing creatures, ascribed their position in the earth to one great phenomenon—the Deluge. Modern philosophers have fashioned Geology into a new science, by discovering in these bodies the evidence, not of one but of many phenomena, including the successive appearance and disappearance of organic bodies, under new forms and combinations suited to the varying conditions of the earth's surface. Of the number of plants which have thus lived at ancient epochs and passed away, some idea may be formed from the fact that the collection of Goëppert, author of 'Les Genres des Plantes Fossiles,' &c., contains 3254 specimens of vegetable petrifactions; namely 236 from transition strata (Cambrian and Silurian), 1548 from the carboniferous, 34 from the "grès bigarré" and "calcaire conchylien," and 61 from the "keuper" (or 34 + 61 = 95 from the trias or new red sandstone), 61 from the lias and oolite, 242 from the green sand, chalk, and gypsum, 742 from lignites, 259 from unknown localities, and 50 of recent forms. These bodies occurred in three conditions:—

1. Stems, leaves, flowers, fruits, interposed between layers of stony or earthy matter, being flexible, and either slightly browned, or in various states (up to the most perfect) of carbonization.

2. Impressions of the bark of plants, the interior of which is either empty or filled with stony matter.

3. More complete petrifactions, in which the whole of the interior mass, as also the individual organs, cells, and vessels of the plant, are *filled* with stony matter; not *changed* into stone, as is commonly said.

The first of these conditions M. Goëppert illustrated by two experiments, in which he imitated the distribution of fossil plants in the shales and grits of various geological epochs. First, by the dry method. Living plants, particularly ferns, were placed between layers of soft clay, which were then dried in the shade and afterwards sub-

jected to heat varying in intensity up to a red heat. According to the degree of heat, the plants were found either slightly browned or perfectly carbonized; and when either powdered coal or asphalte had been mixed with the clay, they exhibited a shining black tint, and adhered to the layer of clay. When the heat had been pushed to redness, and the plants were entirely consumed, impressions of both faces were found, just as in the grits of Silesia. Secondly, by the moist method. The plants placed between layers of clay were plunged 6 feet deep in a ditch, and left there for a whole year; and the result was, that they were more or less browned, as is the case also with plants naturally immersed in the mire at the bottom of ponds, and so strongly resembled the impressions of fossil plants that they might have been mistaken for them.

The second condition has not been fully illustrated by direct experiment, as it requires a combination of circumstances not easily imitated on the small scale. In it the bark of the plants sometimes resembles coal, the impression of all its external peculiarities being found in the surrounding matrix, and that of the internal surface on the stony cast formed within it. In cases like this, the cast and the mould have been taken for different bodies. Sometimes the bark has been reduced to a coaly powder, found between the impression of the mould and the cast; and as in this case the decomposition of the thin bark has preceded the formation of the cast, the cast has filled the mould, and represents therefore the original external surface of the plant, not that of the interior, as in the preceding case. When the process of decomposition has taken place under pressure, the stems are found more or less flattened, and in some calamites the opposite surfaces are pressed close together, the whole internal substance having been removed before the consolidation of the surrounding mass had secured it from the effect of pressure.

In the third condition of vegetable petrifactions, the petrifying matter has infiltrated into and been solidified in the interstices of the cells and vessels, the walls of which have been more or less preserved. The mineral petrifying substances were either silica (the most general mineralizer), carbonate or sulphate of lime (not so common), peroxide of iron, smooth clay, or a mixture of several of these ingredients. This process is still going forward. M. Goëppert received specimens of oak from M. Cotta and from Mr. Laspe, taken from a brook near Gera, which, in a space of time unknown, had been fossilized by carbonate of lime, the presence of which was detected on attempting to saw them: they are sufficiently hard to take a fine polish, their vessels and cells having been filled with carbonate of lime. In a specimen of beech, from a Roman aqueduct in the principality of Buckebourg, the petrifaction is exhibited only in cylindrical spaces which traverse the ligneous structure longitudinally, and were probably vacant spaces occasioned by decomposition, and filled up by the stony matter. The wood surrounding the petrified portions is perfectly sound; and under the microscope the exact identity of the structure of the woody and stony portions can be clearly discerned. On subjecting the specimens to the action of an acid, the earthy matter was removed, and the ligneous texture in the oak was still found to contain tannin, so that perfect decomposition was not a necessary precursor of petrifaction. Peroxide of iron, which is constantly forming, is well suited to the petrifying process: the stave of a cask which had probably been immersed in the well of the castle of Gotha for one hundred and fifty years, had been, especially at the junction of the hoops, petrified by this substance, and was so hard as to take a polish by friction. The iron having been removed by hydrochloric (muriatic) acid, the wood continued in a solid and coherent state. Examining the fossil woods of the ancient world, he found, by treating calcified specimens of various localities and ages, including that from Craigleith, in Scotland, that the same results were observ-

able, the woody fibre being still exposed by the action of very dilute hydrochloric acid. In some specimens, a bituminous oil, resembling in smell a mixture of creosote and petroleum, was obtained,—an additional proof of the formation of bitumen under aqueous pressure.

Wood fossilized by gypsum is very rare: a specimen from Katscha, in Silesia, weighing 4 quintals, is in the museum of the University of Breslau. The ligneous fibre is only in part fossilized, being otherwise flexible and browned. In siliceous vegetable fossils, M. Goëppert removed the silica by hydrofluoric acid, and frequently found the woody fibre so well preserved that it might be used in determining the genus of the plant. In woods which, after having been treated with hydrofluoric acid, exhibit no trace of organic matter, there is little doubt that it has been removed after fossilization, either by long aqueous action or by heat; some slices of the petrified coniferæ of Silesia, still retaining a portion of fibre, were subjected to the action of a furnace, when the fibre was destroyed, and the specimens, before variously coloured, became uniformly white and opaque, though the characteristic structure of the coniferæ was still very distinct. In other cases it would appear that water had been the principal agent, as in many specimens of the fossil wood of Buchau, in the county of Glatz, examined by M. Goëppert, which had been rolled about in a brook running from the mountain, and in which the more they were rounded and had been subjected to the action of the air and water, the less organic matter was discoverable in them, the diminution taking place from the centre outwards. Though, in this instance, the disorganization was effected in so short a time, traces of organic matter have been found in specimens which had been exposed to the air for more than 1000 years? Two specimens of fossil wood from the Desert of Egypt, which, from their appearance, had evidently at some remote epoch been rolled by water, still preserve a large quantity of organic matter. The agatized woods of Hungary occur in the horizontal beds of a conglomerate of pumice which forms the basis of the trachytic group. Externally these agates are beautifully transparent from the absence of organic matter (which however exists in the narrow cells of the annular rings), and from the contained water. Exposed to the flame of the blow-pipe, they lose their transparency, become white and opaque, and, from the dilatation of the water, split along the direction of the ligneous fibre. In the Tokay fossil wood, the colour, as well as the organic matter, is still preserved. In the Antigua agatized palms, the delicate spiral vessels can still be recognized. In general, the more organic matter left, the more coloured the specimen; but at times it takes its tint from the mineral matter itself. If the organic fibre of fossil plants be subjected to heat, it is burnt away, and leaves, as in recent plants, a siliceous skeleton: and when we reflect on all these curious facts, can we refrain from admiration at the thought that not merely the forms of bodies, but actually the organic matter of ancient worlds, has been preserved for our contemplation and study?

Reviewing the various circumstances and conditions of fossil vegetables, in the most remote as in the existing period, M. Goëppert concludes that the same forces which are now in action were sufficient in the past epochs for producing the effects observed, and that the water of the ancient world *did not* possess a higher solvent power than it now does. Water will dissolve about $\frac{1}{1000}$th part of silica, and although a well ascertained recent siliceous fossil is yet a desideratum, the concretions on the bamboo, called tabasheer, and the large quantity of silica deposited in some other living vegetables, particularly in the equisetaceæ, are sufficient proofs of the ease with which it enters into the vegetable structure.

The connection of this inquiry with the formation of coal and lignite is evident. M. Wiegmann made experiments on the formation both of turf and of lignite in the

moist way, and many natural examples might be cited of such formation within comparatively small intervals of time. In the mines of Charlottenbrunn, fragments of ancient carpentry were changed into lignite. Specimens of woodwork sent to M. Goëppert by M. Schroëtter, from the iron mines of Zurrach in Stiria, had been changed into resinous lignite in the space of less than sixty years. M. Liebig states that in disintegration the hydrogen alone escapes, but that in putrefaction oxygen also is disengaged; if, then, this latter change takes place under a high pressure and at an elevated temperature, considerable quantities of carbonic acid will be disengaged, and much carbon be deposited in combination with a part of the hydrogen of the organic substance, coal and some lignites having probably been the result of such a metamorphosis, M. Link has also endeavoured to show, by comparative microscopic observations, that turf and coal are analogous in structure, and have proceeded one from the other; and the occurrence of stems of trees in coal is not opposed to this view, as they are also frequently found in successive layers in deep turf, as, for example, in that of Ireland. The formation of coal by immersion in water, under pressure, was however suggested long since by Dr. M'Culloch. A similar inquiry has been instituted by Messrs. Marcel de Serres and L. Figuier, into the general principles of petrifaction, and, specially, as an illustration of them, into the petrifaction of shells in the Mediterranean, these authors differing from M. Goëppert in the assumption that the waters of the ancient ocean possessed a higher solvent power than they do at present. In fact, in this as in every other active force, the tendency is to a resulting equilibrium. *If* it has *now been attained*, the same processes will continue, but without producing any difference in the great whole of the animal, vegetable, and mineral kingdoms: if it has not been attained, such a difference, however gradually, must be produced. The long continuance of the present assemblage of created beings, without any apparent variation in the effective condition of the atmosphere, is a strong reason for believing that an equilibrium has been attained; and it may be assumed, that until such had been the case, the variations must have been sufficiently rapid to induce a much more frequent change in the aggregate of organic existences than could now be expected to take place in a world which, so far as evidence can be obtained, has only lost, during 6000 years, about twelve vertebrate animals, principally from the action of man, although the distribution of such animals has been materially modified by the local extinction of some and the lateral extension of other species.

Messrs. Serres and Figuier remark, that in order to induce the petrifaction of organic bodies, in which process the animal matter is replaced by mineral matter which preserves their most delicate forms and markings, they must be plunged in a considerable body of water, containing in solution a sufficient quantity of siliceous and calcareous salts. The first part of this condition was specially fulfilled in the ancient world, when the waters occupied a much larger space than they now do, as shown by the general nature of geological deposits; and as regards the second, there can be no doubt that the dissolved salts were in sufficient abundance. In palæozoic petrifaction, carbonate of lime was the principal agent, and the fossilization was complete in proportion to the abundance of that salt present. In gypseous, argillaceous, and even sandy deposits, the petrifaction is imperfect, the shells of mollusca being often only partly preserved; whereas in calcareous deposits it is complete. The solution and deposition of lime affords one of the many examples which occur in nature, of a balance between the formative and destroying causes constantly in action. Innumerable springs charged with carbonic acid dissolve the carbonate of lime of ancient formations, and carry it to the ocean, whilst the mollusca, &c., again withdraw it, and liberate the carbonic acid to return to the atmosphere. The shells

of the mollusca again pass into new mineral deposits, either whole or triturated into powder; and the same may be said of the corals and other zoophytes.

Silica is the next most important petrifying substance, and even exceeds carbonate of lime in the extreme delicacy and fidelity of the restoration it produces. Those portions of the organic body which were capable of preserving their form for a long time, are usually found petrified by carbonate of lime, but those of less consistency, such as the purely animal portion, by silica; the ligaments of gryphæa being often silicified, whilst the shells are calcareous; the shells of ananchites and other echinida of the green-sand being generally calcareous, whilst their interior is either partially or wholly filled with a siliceous cast; the alcyonia and sponges being usually silicified, though disseminated, as in the chalk, in calcareous rocks. In regard to the solution of silica, it has already been stated that the water of almost all mineral and thermal springs contains a portion, that it occurs in most rivers or streams, that it abounds in the stems and membranes of many vegetables, that heat and pressure combined favour its solution,—as is shown by the great quantity deposited at the foot of the boiling Geysers of Iceland,—that the presence of an alkali proceeding from the decomposition of felspathic rocks greatly favours its solution; and further, that in the gelatinous or nascent state, in which it always occurs on the decomposition of a mineral, it is readily soluble. As, therefore, silica in solution was required for the formation of rock crystal, so, in a gelatinous state, it produced calcedony, opal, and even some of the flint and chert of various geological formations.

Oxide of iron, anhydrous or hydrated, and bisulphuret of iron, have also entered into the formation of fossils: in respect to the latter, the action is, as in silica, principally on the animal substance; as, for example, the ammonites in shale exhibit a mere film of shining iron pyrites, which has replaced the animal membrane.

The second section of Messrs. Serres and Figuier's researches relates to the highly interesting question of the existence of *recent* petrifactions in our present seas, analogous to those of ancient geological times. In the Mediterranean, shells are immersed in a sufficiently considerable mass of water which contains in solution a notable quantity of carbonate of lime: the conditions are therefore present, and the analogous result appears to follow.

The Officers of the French Engineers submitted to Messrs. Serres and Figuier specimens, from the neighbourhood of Algiers, of masses of shells transformed into a crystalline white limestone of a peculiar lustre, like that of alabaster. In these shelly masses, small rolled pebbles are observed incrusted by a stalagmitic glaze, which appears to be similar to the cementing substance which binds the pebbles together. The shells are all of recent species of the genera pectunculus and cardium, with a few univalves, and the Officers of Engineers considered the rock decidedly of recent origin. The very remarkable recent conglomerate formed on the shore of Santa Maura, and at other localities, and which in its cohesion is fully equal to many ancient rocks of the same description, is another example; and as manifesting the continued tendency to such aggregations, even from other agencies, may be cited an interesting specimen, found in Santa Maura by Mr. Cottam, in which several pebbles had been agglutinated firmly together by the decomposition of a nail, to which they still strongly adhered.

The Desert which crosses the road from Cairo to Suez is dotted by trees which seem to have been petrified just as they stand, and within the present epoch. The trees are only covered by sands and gravel, the whole reposing on a limestone containing oysters, the texture and colour of which are so little changed that they might be supposed only just abandoned by the sea, and can only be considered a modern formation. On the territory of Kurneel, in India, a thermal spring has formed an

abundant calcareous deposit, including numerous shells of the genera melania and planorbis, which are in various stages of petrifaction, some being entirely converted into calcareous spar, and some covered by crystals of quartz.

That shells should be petrified, it is necessary that they should remain a long time immersed in water, or in the sea; as when abandoned on the shore, they exfoliate and disintegrate, are gradually broken up, but not petrified. When shells are abandoned by the animals, the first change they experience is a loss of colour, as is the case also with the solid tubes of annelids (dentalium), and the stony polypifers: the substance is then altered, many of the tubercles, ribs, &c., disappear, and the structure of the internal laminæ is displayed; and as the process goes on, the interior of the shell becomes filled by an agglutinated and hardened sand, until the change has been so perfected, that, had not the crystalline carbonate preserved the form of the shell, it would have been impossible to recognize it. Some striking examples of this change are adduced; and in reply to the objection sometimes urged, that such fossils may have been washed out of tertiary beds, Messrs. Serres and Figuier observe,—1stly, that shells are found in the Mediterranean in all stages of the petrifying process, from simple discoloration to the complete transformation into crystalline carbonate of lime; 2ndly, that the molecular structure of recently petrified shells is very often different from that of ancient fossil shells, the first being usually crystalline, the others usually compact; though it is right to state, that in many ancient fossil shells the crystalline structure of shells is very perceptible, distinguishing them at a glance from the surrounding compact limestone.

Messrs. Serres and Figuier conclude by an interesting comparative analysis of the substance of living, of recently petrified, and of fossil shells, having selected genera common to the three epochs of the comparison, so that the natural or original condition of the shells compared having been the same, the change may be taken as a correct index of the effects of petrifaction. One of their examples will be sufficient, namely that of the genus Ostrea:—

OYSTERS.

	1. Ostrea edulis, variety C, living in Mediterranean.	Ostrea edulis, variety C, petrified in Mediterranean.	Ostrea, near O. hippopus, Upper Marine, Pliocene.
Animal matter . .	3·9	1·5	0·8
Carbonate of lime .	93·9	96·3	96·5
„ magnesia .	0·3	0·1	1·4
Sulphate of lime .	1·4	0·7	0·5
Phosphate of lime .	0·5	0·0	0·0
Oxide of iron . .	(trace)	1·4	0·8
	100·0	100·0	100·0

So that the recent shells petrified in the bosom of the Mediterranean have undergone the same change as those found in the beds of the tertiary epoch, and we may conclude with our authors, that the phenomena of the ancient world are still repeated in the present, and that the same laws have at all epochs produced similar phenomena; unity being at all times an essential character of the works of nature.

THE MEANING, ORDER, AND OBJECT OF GEOLOGICAL FORMATIONS OR SYSTEMS.

From the preceding observations a right conception may be formed of the true meaning of the term formation or system, in geological science. Under this term, therefore, is understood an assemblage of rocks or strata which were formed or deposited at some particular epoch of the earth's history, and by their mineral and

mechanical structure point out the physical agencies which were then operating in modifying the earth's crust; whilst the fossil relics they contain indicate the nature of the vegetables and animals which were then living. From a description then of each successive formation, we obtain, so far as the imperfection of the remaining records and the still greater incompleteness of our inquiries will permit, a knowledge of the inhabitants of the earth, and of the plants which either sheltered or supported them at so many successive epochs of the earth's history.

Such an investigation as this is surely one of immense interest both in a philosophical sense, and in a practical sense, as there is that relation between natural causes and effects which enables the accurate observer to deduce the one from the other, and thus to infer the probability of the existence of some peculiar natural product from the presence of another which in other localities he had observed associated with it. And here it may be observed, that in the survey thus taken of the condition of the world, both as regards its organic and inorganic constituents, during the lapse of countless ages, and amidst many catastrophes, no discovery has been made of any new principle or law; for though many new forms and remarkable adaptations of structure to the varying functions required by the altered conditions of life, may be observed, everything proves that the same physical and organic laws have guided the world's movements and influenced its mineral, animal, and vegetable condition, from the earliest epoch the records of which have been preserved in the stony tablets which the geologist studies and explains, up to the present epoch, when sentient beings are in existence to observe and to record them.

In the earlier period of geological science, the terms primary and secondary were adopted,—the first being applied to those rocks, as granite, gneiss, mica-slate, etc., which were then considered to be portions of the original crust of the earth,—and the secondary to those of subsequent mechanical origin; and when, at a subsequent period, fossils had been recognized as the relics of real organic beings, they were considered peculiar to the secondary strata.

Ere long it appeared that some rocks, partaking of the characters of the primary, contained organic remains, and a new term, "transition," was adopted to express this supposed relation or passage, though of course there could not really have been such a passage. The progress of science has, however, gone further, and has now proved that the massive primary rocks, such as granite, greenstone, hornblende rock, etc., are sometimes secondary to many of the stratified and fossiliferous rocks; and that the stratified primary rocks, such as gneiss, mica slate, and clay slate, are of very different ages in different countries, being the strata immediately below the lowest unchanged sedimentary rocks of the district which have undergone that peculiar change implied by the term metamorphic: so that in a country occupied by the formation called Silurian, or by the Cambrian, if separated from it, the metamorphic rocks must either be classed in the lower part of that system, or be considered strata lower than the lowest known fossiliferous deposits; whereas in a country occupied by the great cretaceous or chalk formation, the metamorphic rocks may be of any date more remote than that of the chalk, and possibly therefore more recent than many other fossiliferous deposits.

The use of the terms primary and secondary has been therefore much modified, and the term transition abandoned; Sir Charles Lyell and Professor Phillips having proposed to apply the terms primary, secondary, and tertiary, as qualifying epithets as well to the massive crystalline and metamorphic rocks, as to the ordinary sedimentary and fossiliferous deposits; so that there may be primary granite, primary lava, primary gneiss, primary mica-schist, and primary fossiliferous strata; and in like manner, secondary and tertiary rocks with the same designations.

The term primary, or that of Palæozoic, appiled to fossiliferous strata, replaces therefore the old term transition, and embraces all those strata containing organic remains which were formerly described as à transition, intermédiaire, grauwacken, etc. The secondary, or Mesozoic, embraces as heretofore a long series of formations, extending upwards to the chalk inclusive; the tertiary, or Cainozoic, another series, which comes up to the base of the present system; whilst the post-tertiary may be considered part of another formation yet to be completed. In a natural arrangement, there ought to be an equality in the amount of change between the great groups; but as yet, the change from the secondary to the tertiary appears, even after the more recent inquiries and modifications, more abrupt than that from the primary fossiliferous to the secondary.

After these few remarks on the great divisions admitted in Geology, the subdivisions may be studied with advantage, being first exhibited in a tabular form and descending order. In practically applying the knowledge thus obtained, the geological inquirer must next ascertain the relative position and order of sequence of the beds he is examining, and for this purpose determine the strike and dip of the strata. Many very simple methods of roughly obtaining these data will occur to every Engineer, but as it is often very difficult to determine by the eye alone the true inclination of planes, a clinometer may be used for the purpose, one of which is represented, Plate VII. fig. 36, and which may be modified or imitated by any tolerable mechanic. The true strike of the strata is so often modified by elevating forces that it must not be assumed to be coincident with the direction of the valley in which the strata occur, but be determined in relation to the true dip of the plane. The sequence having been determined, fossil evidence should then be sought for, in order to establish the zoological relations of the strata, and thereby to fix their geological positions.

Class.	Order.	Groups. Marine.	Groups. Fresh-water.	Remarkable Localities.	French Synonyms.	German Synonyms.	Massive Volcanic and Metamorphic Rocks.
Quaternary, or Post-Tertiary of Lyell. These deposits must necessarily be most extensive under existing seas and lakes.	Recent.	Sand and gravel and mud. Sand consolidated. Gravel do. Calcareous grits, enclosing corals, shells, pottery, and human skeletons. Coral limestone, consisting of corals, shells, etc.	Peat, with fresh-water shells, bones of land animals, human remains, and works of art. Travertin, or calcareous deposits from mineral springs.	Delta of Rhône in Mediterranean. Shore of Santa Maura, and other parts of Ionian Sea. Shore of Guadaloupe. Newer part of coral reefs in Pacific. Solway Moss, Irish bogs; a rude hut found in Galway, under more than 20 feet of turf. Italy. County of Mayo, Ireland, incrusting mosses, etc.; counties of Derry and Tyrone.	Période Jovienne, or actuelle, or postdiluvial. Including Terrains alluvials, and Terrains lysiens, or calcareous and siliceous deposits from solution.	Alluvial-gebilde; Including Turf, beds of infusoria, and bog iron ore.	Volcanic eruptions continue.
	Post-Pliocene.	Clay, sand, and volcanic tuff, with recent shells. Limestone casts of recent shells. Boulders, in sand, gravel, and clay.	Sand, clay, and lignites, with shells and fish-scales. Shell marl, with fresh-water plants, and masses of solid limestone. Silt, with land and fresh-water shells.	Ischia, and other portions of volcanic district. Scandinavia. Mud cliffs of Norfolk. Beaufort, Canada. Beautiful examples of clay, of deep sands, and of gravel, supporting erratics in Ireland. Mundesley. Bakie, Forfarshire. Lacustrine shell marl, frequent in Ireland, and contains the antlers of Megaceros Hibernicus, or Irish elk, the range of which has been recently much extended. Valley of Rhine.	Here commences Brongniart's Période Saturnienne, or antediluvial. Terrains clysmiens, or detritic. Including Diluvium, boulders, and erratics. M. Brongniart classes part of the English crag here, which belongs to the next class.	Diluvial-gebilde; Including Boulders and the 'los,' or sand, gravel, and loam, which contains the bones of extinct mammalia.	The action of the present volcanoes may be considered to have commenced in this period.
The action of Glaciers probably commenced in the next earlier period, and has ever since continued.							

TABULAR VIEW—*continued.*

Class.	Order.	Groups. Marine.	Groups. Fresh-water.	Remarkable Localities.	French Synonyms.	German Synonyms.	Remarks on Volcanic and Metamorphic Rocks.
tiary. tinctly recognized recent shells.	Newer Pliocene. Shells principally of recent species.	Loam, with marine shells. Limestone, and calcareous conglomerate.	Loam, sand, and gravel, with fresh-water shells, and bones of extinct quadrupeds.	Glasgow. Sicily. Brentford, etc. Valley of Thames.	Here begins Brongniart's terrains yzemiens, or of sediment. And terrains yzemiens thalassiques, or, terrains de sédiment supérieurs, or terrains tertiaires.	Molassen generally for tertiary. Obere braunkohlen formation (fresh-water). Grobkalk formation. Untere braunkohlen formation.	Sir C. Lyell ascribes the volcanic formations of the Val di Noto in Sicily, consisting chiefly of basalt, to this period.
	Older Pliocene. Half, or more than half, of the shells recent.	Norwich crag: shelly sand and loam, with marine shells, and bones of land animals. Red crag: red ferruginous quartzose sand, with rolled shells. Coralline crag: white calcareous sand, passing into a soft stone, with comminuted coral and shells. Sub-Apennines: yellow sand and blue clay.	Sand, with fresh-water shells.	Coast of Norfolk. Suffolk. Orford, Suffolk. Sub-Apennines, Italy. The blue clay extensively developed at Corfu, rising to an altitude on Monte Sante Decca of about 800 or 900 feet. Postwick, Norwich.	Thalassiques protéiques, or terrains marins superieurs. Terrains epilymniques, or lacustres, or d'eau douce supérieurs. See next group.	Molassen. See ante.	Submarine volcanic tuffs of Tuscany and the Campagna of Rome associated with pliocene strata of the Sub-Apennine Hills. Extinct volcanoes of Catalonia. (Lyell.)

Ter In which first appear dis						
Miocene. About one quarter of the Shells recent.	A small probable Miocene deposit in the Isle of Arran, the only representative in Great Britain.					
	Faluns of Loire: similar aggregation, and marl. Bordeaux beds: argillaceous and marly deposits.		Valley of Loire, near Nantes; Angers, Tours, and Blois.	See preceding group.	Sir C. Lyell places the braunkohlen in this group, but Cotta divides it into two associations; the one, as the upper, with the siliceous limestone and millstone of the Paris basin; the other, as the lower, with the London Clay. See next group.	Extinct volcanoes of the Eifel and Lower Rhine. (Lyell.) Extinct volcanoes of Hungary. Auvergne volcanoes continue in action in this period. (Lyell.)
			Bordeaux and Dax.			
	Yellow sandstone, with marine shells, beds of clay, and lignite.	Blue clay and yellow sand, with mammalian bones and fresh-water shells. Argillaceous and marly beds, with land and fresh-water shells.	Corfu. An estuary formation, as seen in the citadel.	Terrains epilymniques. Or, Terrains lacustres, or d'eau douce supérieurs.		
			Upper Val d'Arno.			
			South of Bordeaux, at Sauceats.			
	Yellow sandstone.		Corfu. This sandstone, with beds of gypsum, is extensively developed.			
Eocene. Now subdivided into Lower, Middle, and Upper. Shells generally extinct.	Sands. Calcaire grossier, or coarse limestone. London clay.		Fontainebleau. Paris basin—geologically above London Clay. (Prestwich.)	Thalassiques tritoniens.	Lower braunkohlen. Grobkalk formation.	Volcanic eruptions of Auvergne begin. (Lyell.) The basalt of Ireland overlies the chalk, and cuts through it: hence it is, in part, more recent than that formation.
	Clay and sand. Woolwich Bed. Thanet sand. Conglomerate of white limestone, pebbles and flints.	Calcaire siliceux, or Siliceous lime. Siliceous millstone. Green, white, and gypseous marls and gypsum.	London and Hampshire basins, including Isle of Wight. North of Germany. Corfu. The remarkable vesicular limestone, weathering ferruginous, and containing minute pebbles of white limestone, probably is of this epoch. Paris basin. Isle of Wight. Ionian Islands, in nummulated limestone.	Thalassiques palæothériens, or, Terrains lacustres inférieurs.	Süsswasser kalkstein, with which is associated the upper braunkohlen.	

TABULAR VIEW—*continued.*

Class.	Order.	Groups. Marine.	Groups. Fresh-water.	Remarkable Localities.	French Synonyms.	German Synonyms.	Remarks on Volcanic and Metamorphic Rocks.
Secondary.	Cretaceous.	1. Maestricht beds: soft yellowish white limestone, resembling chalk with siliceous masses. Aggregate of corals. baculite limestone. 2. Chalk with flints. 3. Chalk without flints and chalk marl. 4. Upper green-sand: marly stone, and sand with green particles. Layers of calcareous grit. 5. Galt: blue clay, with numerous fossils, passing into calcareous marl in the lower parts. 6. Lower green-sand: grey, yellowish, and greenish sands, ferruginous sands and sandstones, clays, cherts, and siliceous limestones.		St. Peter's Mount, Maestricht. Cassel, near Mentz. Faroe, Denmark. Valognes, Normandy. It is probable that the upper portion of the white limestone of the Ionian Islands, as at Paxo, containing nummulites, belongs to this epoch. North and South Downs, and parts of Kent, Surrey, and Sussex; Isle of Wight; Yorkshire; North of Ireland. Meudon, Rouen, Beauvais, France. Some portion of the white limestone of the Mediterranean belongs to this epoch. Le Blanc (Indre); Rethel (Ardennes), Isle d'Aix.	Here begin Terrains yzemiens pélagiques. (Danien.) Pélagiques crétacés. 1, 2. Craie blanche. (Senonien). 3. Craie tufau. (Turonien). 4. 5. Glauconie crayeuse. Cénomanien. 6. Pélagiques arénacés. Albien. Including Glauconie sableuse. Sable ferrugineux marin. Lignite of Isle d'Aix. Aptien.	Kreide Gruppe. 1, 2, 3, being kreide formation. 4, 5, 6. Quadersandstein formation. And to these is added our Wealden, as 'wald formation.'	The ophiolites, or serpentine lavas of the Morea, erupted in this period. Some portion of the basalt of Ireland probably erupted during or prior to this epoch, as portions of it are found immersed in the chalk. It has been conjectured that the mica slate of Asia Minor belongs to this epoch.
	Wealden.		1. Weald clay: clay (non-calcareous), sometimes including thin beds of sand and shelly limestone. 2. Hastings sands: grey-yellow, and reddish-brown sands, sandstones,	Central parts of Kent, Surrey, and Sussex. Isle of Purbeck. Bas-Boulonois, Beauvais.	Pélagiques veldiens. Including Argile veldienne. Sable ferrugineux lacustre. Calcaire lumachelle Purbeckien.	Wald formation, associated by Cotta with the cretaceous Order, as the lower group.	The ophiolites may be considered to extend over this period.

			clays, calcareous grits passing into limestone.				
	Oolitic, or Jura Limestone.	1. Portland beds: coarse shelly limestone, fine-grained white limestone, compact limestone more or less oolitic, beds of chert.	Purbeck beds: various kinds of limestones and marls. These are sometimes placed in the previous division.	Isle of Portland. Tisbury, Aylesbury.	Pelagiques epiolithiques.		
				Part of the white limestone of the Mediterranean belongs to this group.	Calcaire Portlandais, Portlandien.		
		2. Kimmeridge clay: blue and greyish-yellow slaty clay, containing gypsum, bituminous slate, or Kimmeridge coal.		Near Kimmeridge. Sunningwell, near Oxford. Cap la Hève au Hâvre. Honfleur.	2. Marne argileuse Hâvrienne. Kimmeridgien.	Jura formation, being, according to Cotta, the upper member of the Jura gruppe.	Sir C. Lyell considers the serpentinous traps of the Morea to belong partly to this epoch, and thinks it possible that the volcanic rocks of the Hebrides may have originated contemporaneously with the lias and oolite, which they traverse and overlie. It is also highly probable that some of the basalts of Ireland were even as ancient as this epoch. The melaphyr and mandelstein (amygdaloid) are by Cotta carried into it.
		3. Coral rag: calcareous shelly freestones, largely oolitic; coarse limestone, full of corals; yellow sands; calcareous siliceous grits.		Headington, near Oxford; Farringdon; Calne; Steeple Ashton, Somersetshire; Boulonois, Mortagne.	3. Calcaire corallique, with Sable ocreux, Corallien.		
		4. Oxford clay: dark blue tenacious clay with septaria; bituminous shale; sandy limestone (Kelloway rock); iron pyrites; gypsum.		Abundantly near Oxford. New Malton, Yorkshire; Lincolnshire, Cambridgeshire, Huntingdonshire, Somersetshire, Dorsetshire. Kelloway Rock.	4. Marne Oxfordienne. Oxfordien. Marne calcaire. Callovien.		
		5. Cornbrash: grey or bluish rubbly limestone, with layers of clay.		Malmesbury, Atford, Wraxall.	Pélagiques Jurassiques, supra-Jurassiques.		
		Forest marble: calcareo-siliceous sand and grit; thin fissile beds of limestone, with clay partings; coarse shelly limestone.		Wichwood Forest, Oxon; Frome.	5. Calcaire schistoïde. Calcaire lithographique.		

TABULAR VIEW—*continued.*

Class.	Order.	Groups. Marine.	Groups. Fresh-water.	Remarkable Localities.	French Synonyms.	German Synonyms.	Remarks on Volcanic and Metamorphic Rocks.
continued.	Oolitic, or Jura Limestone—continued.	6. Great oolite: white and yellow oolitic freestone; coarse shelly limestone; layers of clay. Stonesfield slate: oolitic limestone, with remains of land animals, birds, etc., and sea shells. 7. Fullers' earth: clay, containing fullers' earth. 8. Inferior oolite: soft freestone; sand with calcareous concretions.		Bath, Burford, Bradford, Caen. Stonesfield, near Woodstock. Near Bath. Cotteswold Hills. Dundry Hill. Mr. M'Coy places *the coal* of Australia here, though the underlying limestone corresponds to the mountain limestone.	Médio-Jurassiques. Bathonien. 6. Calcaire compacte commun, or Oolithe miliare. Marnes calcaires Jurassiques. Infra-Jurassiques. Calcaire compacte oolithe ferrugineuse.		
	Lias.	Lias: shale, and sandy marlstone. Blue, white, and yellow earthy limestone, usually in thin beds, interstratified with clay, often slaty and bituminous.		Lyme Regis, Dorsetshire; and in Somersetshire and Yorkshire. Ireland, as a thin seam under the chalk escarpment, and probably extending upwards into the oolites; or if not, exhibiting the lias sandstone of Brongniart. Lignite is associated with this formation in the Irish locality, as in Würtemberg, France, Germany, and Swabian Jura.	Terrains abyssiques. Abyssique du lias, composed of sandstone, of lias, marly gryphite limestone, alum shale.	Lias formation, Including Lias shale, lias limestone, lias sandstone; the lias shale being sometimes called a posidonia shale. Divided by Oppel into Upper, Middle, and Lower lias, or Toureien, Liasien, and Sunzmurien.	Sir C. Lyell considers, as before observed, that some of the volcanic rocks of the Hebrides may belong to this epoch It is highly probable that basaltic eruptions occurred in Ireland during this epoch, and that the great basaltic mass is, in fact, a series of alternating eruptive and metamorphic sedimentary strata. Granite uplifted at this epoch in the Alps.
		1. Keuper, or variegated marls: red, grey, green, blue, and white marls,		Keuper: neighbourhood of Vosges; Würtemberg, Westphalia, Nuremberg.	Abyssique du keuper. 1. Marnes keupriques, associated	1. Keuper formation. Keuper sandstein, with marls, gyp-	Sir H. De la Beche considers the trappean rocks associated with the new red sandstone of Devon-

Secondary—	New Red Sandstone, or Trias.	sandstones, conglomerates, and shales, containing gypsum and rock salt. Bone bed: dark coloured limestone, with remains of peculiar fishes; red and green marl. 2. Muschelkalk: grey, blue, and blackish limestone, with alternating clay and marl, and with siliceous layers and nodules. 3. Variegated sandstone: red, white, blue, and green siliceo-argillaceous sandstone, often micaceous, and containing gypsum and rock salt.		Bone bed and underlying marls, Axmouth; bone bed also at Aust, Lancashire; and in Ireland, in a very confined locality at Lisnagrib, on the face of Ben Evenagh, county of Derry. Not yet discovered in England or Ireland; extensively developed in France and Germany. Würtemberg; counties of Stafford, Salop, and Worcester; Derry and Tyrone and Antrim.	with sandstone, marly limestone, plastic clay, gypsum and sea salt. 2. Abyssiques conchyliens. Calcaire conchylien, including marly limestone with quartz and galena, fetid and encrinital limestones, with gypsum and sea salt. Dolomite. 3. Abyssiques pœciliens. Psammite or grès bigarré, lignite, clay, and dolomite in nodules.	sum, salt, dolomite, shale, and impure coal. Muschelkalk formation. The well known muschelkalk, with marl, gypsum, salt, etc. Formation des bunter-sandsteins. The bunter sandstein, with variegated marls and red clay; gypsum with rock salt.	shire as contemporaneous volcanic deposits. M. Cotta introduces the melaphyr eruption and the formation of metallic veins here; also eruptions of porphyry and greenstone. There can be little doubt that the gneiss, mica schist, and other metamorphic rocks of a large portion of the Alps, were strata originally of this or the lias epoch, though altered during the epochs subsequent to the cretaceous: granite associated in these changes.
	Magnesian Limestone.	1. Magnesian limestone: marl slate, shelly limestone, variegated marls, yellow magnesian limestone. Dolomitic conglomerate, being fragments of subjacent rocks, with dolomitic cement.		Nottinghamshire, Derbyshire, Yorkshire, Durham, and Northumberland. Bristol.	Abyssiques pénéens. Fetid limestone, gypsum, dolomite, and calcaire pénéen; schiste bitumineux, with copper and mercury.	Zechstein formation. Rogenstein, or roestone. Stinkstone: gypsum and dolomite. Zechstein, sometimes dense, sometimes porous grey limestone.	See the remarks made on the New Red Sandstone Order.

TABULAR VIEW—*continued.*

Class.	Order.	Groups. Marine.	Groups. Fresh-water.	Remarkable Localities.	French Synonyms.	German Synonyms.	Remarks on Volcanic and Metamorphic Rocks.
Secondary—continued.	Magnesian Limestone—continued.	Zechstein of Germany: limestone associated with marl slate, containing copper ore and impressions of fish. 2. Red conglomerates, with red sandstones and red marls.		Mansfeld, in Thuringia. Exeter. Mansfeld.		Kupfer-schiefer, or copper slate, a bituminous marly schist. Weissliegendes, a conglomerate, sometimes with copper ore. 2. The rothliegenden are by Cotta joined to the next order.	
	Carboniferous.	1. Coal measures, marine and fresh-water: sandstones, conglomerates, clays, shales, limestone, with ironstone, and interstratified beds of coal. 2. Millstone grit: coarse quartzose sandstone; sometimes used for millstones; usually devoid of coal. 3. Mountain limestone: grey, compact and crystalline limestone, abounding in lead ore in North of England, and alternating with coal measures in Scotland, containing corals and shells.		1, Northumberland, Durham, Yorkshire, Lancashire, Staffordshire, Somersetshire, South Wales, Valleys of Forth and Clyde, Ireland, Liége, Westphalia, Silesia, North America, Bohemia. 2. South Wales and Bristol coal-fields; Yorkshire; supposed also Ireland. 3. Mendip Hills, Derbyshire; Yorkshire, Durham, Northumberland, Lanarkshire, Linlithgowshire, Ireland, extensively, North-West of Germany, Belgium, North of France, Australia, though the underlying coal is supposed by Mr. M'Coy to be oolitic.	Abyssiques houilles, and abyssiques rudimentaires. Houille and anthracite, with various psammites, or grits. Phyllades, or shales. Arkose molaire, and arkose miliaire, or millstone grits, and minophyre, eurite amphibolique, melaphyre, amongst the trap rocks; and abyssiques carbonifères, including calcaire carbonifère, or mountain limestone, and psammite rougeâtre, or old red sandstone.	Cotta places the rothliegenden formation at the top of this Order, then Steinkohlen formation, and Kohlenkalkstein formation, with Formation des alten rothen sandsteins at the base.	Basalts, wacke, tuff, green stone, appear to have been erupted at various periods in this order of formation, as specially observed by Dr. Fleming. Granite has been forced up in this epoch, or immediately subsequent to it, as shown by its effects on the strata.

Secondary, the lower part possibly Primary.	Devonian, or Old Red Sandstone.	1. Yellow sandstone. 2. Red and green marls, red sandstone, concretionary limestone, called cornstone, conglomerate. 3. Tilestone and grey paving stone, red and green shale, micaceous grit, grey sandstone, with peculiar fishes. 4. In age the same as above. Green chloritic slates and sandstone, with shells and other fossils. 5. In age the same as above. Blue crystalline limestone, with corals, shells, and other fossils of peculiar species, but with some common to the carboniferous and Silurian group.		Dura Deu, Fife; also in Ireland. Herefordshire, Forfarshire. Ireland, exclusive of cornstone, not yet found. Sidlaw Hills, Forfarshire, Caithness, Cromarty, Ireland. South Devon, Cornwall, Eifel, Ireland. The Order extensively developed in Russia. South Devon, Eifel, Gerolstein. It is in respect to this apparent mixture of fossils, that I have suggested, in reference to the old red sandstone of Tyrone and Fermanagh, that part of it is a drift deposit contemporaneous with the Silurian, and the other equally contemporaneous with the carboniferous.	Included by Brongniart as psammite rougeâtre in the coal formation.	Included by Cotta as formation des alten rothen sandsteins in the carboniferous formation.	Eruptions of trap rocks in this order. Granite and syenite upheaved during this epoch; that of the Malvern Hills having acted on the Silurian strata, and induced a metamorphic condition in them. The remarkable syenite of the county of Tyrone is probably of this age. The metamorphic schist of the county of Antrim may possibly have belonged originally to strata of this epoch.
Primary.	Silurian.	1. Ludlow rocks: argillaceous limestone, sandy shale. 2. Wenlock limestone: coralline limestone and ar-		Ludlow Castle, Aymestry, and Woolhope. Wenlock Edge. Dudley.	Terrains hemilysiens of Brongniart, or semi-compact transition strata.	Obere grauwacken formation. Grauwacke and grauwacke slate, limestone and dolo-	Sir R. Murchison considers that eruptions of trap have occurred in this epoch. There is no doubt that granite has also been upheaved,

TABULAR VIEW—*continued.*

Class.	Order.	Groups. Marine.	Groups. Fresh-water.	Remarkable Localities.	French Synonyms.	German Synonyms.	Remarks on Volcanic and Metamorphic Rocks.
Primary—continued.	Silurian—continued.	gillaceous shale, with nodules of earthy limestone. 3. Caradoc sandstones: micaceous sandstone and shelly limestone, quartzose grits and sandy limestones. 4. Llandeilo flags; calcareous flags, sandstone, and schist.		Haderly; May Hill, Gloucestershire; East flank of Wrekin, and Caer Caradoc; Ireland, Desertcreat Parish, county of Tyrone. Llandmidod. Llandeilo. Extensively developed in Russia and North America, and occurs in the Falkland Islands.	Including Hem. calcareux, or limestone division, in which the Silurian is in part confounded with the mountain limestone. H. fragmenteux, or sandstone division. H. schisteux, or slate division; H. talqueux, or talc-schist division; the former transition series merging into what Brongniart calls, as below,	mite, with quartz schist, siliceous schist, alum schist, anthracite, distinguished by the fossils of the English Silurian system.	and metamorphic rocks formed during it. The granite of the county of Down may possibly be of this epoch, and the schists of that county older.
	Cambrian.	Stratified rocks, supposed older than Silurian by Professor Sedgwick, and being of great thickness in Wales, named Cambrian. No assemblage of organic remains distinct from Silurian yet discovered.		Wales; Cumberland, etc.	Terrains agalysiens, or terrains primordiaux, to the upper division of which he allots the killas of Cornwall.	Untere grauwacken formation. Grauwacke and grauwacke schist, with limestone, etc., as above.	Granite has been upheaved during, or prior to, this epoch, and metamorphic rocks, originally of this age, as well as others anterior to it, exist. It is probable that the mica schists of Derry were originally either Cambrian or Silurian strata.

Table of Comparative Thickness of Strata.

Class.	Order.	Group.		Germany, by Cotta.	England, by Phillips, and others.
		Marine.	Fresh-water.	Feet.	
	Recent.				
	Post-Pliocene, or Glacial.	Erratics. Gravel, sand, and mud.		100	
Tertiary.	Pliocene, old and new.	Marine.		80	1248
	Miocene.		Fresh-water.	300	99
	Eocene.			Total 380	1347
Secondary.	Cretaceous, excluding the Wealden, which forms the next class.	All marine.		1800	1080
	Wealden.		Fresh-water.	Westphalia 600 Saxony 30	900
	Oolitic, or Jura Limestone.	All marine.		400	1350
	Lias.	All marine.		200	
	New Red Sandstone.	All marine.		1500	900
	Magnesian Limestone, including red conglomerate	All marine.		1650	300
	Carboniferous, without old Red Sandstone.	Mixed marine and	Fresh-water.	600	2100 to 3000
	Devonian, or old Red Sandstone.	Marine.		From 150 to 10,000 Total ... 16,750	Variable many thousand.
Primary.	Silurian. Cambrian.			Cotta unites these in one formation. Total ... 6000	Many thousand. feet.

According therefore to Cotta, the total thickness of stratified fossiliferous deposits may be assumed as 22,750 feet, or about 4¼ miles, exclusive of the variable and uncertain deposits of the existing period. Such estimates can however be considered only very rough approximations, as the thickness of each deposit may be expected to vary in every locality, and to undergo very material modifications both in the character and in the proportions of its several parts.

GENERAL AND PRACTICAL REMARKS.

In these remarks the descending order will not be followed, but the lowest recognized strata will be first noticed, and each successive formation, growing as it were one out of the other, will in order come under review. But first it is necessary to bear in mind that the old notion that granite, and other massive crystalline rocks, as well as the crystalline schists, were primitive, or a part of the original crust of the earth, has been abandoned and replaced by one which admits that granite, etc., may have appeared on the surface at every geological epoch; and that the crystalline

schists may, in like manner, have been produced in their present form by metamorphic action at various periods. To express this compound relation of the schists, first, by original deposition, to the strata underlying the rocks now resting upon them, and, secondly, by metamorphic change, to an epoch or formation probably posterior to those rocks, Sir C. Lyell has proposed a compound nomenclature representing both facts; as, for example, Ante-Cambrian carboniferous metamorphic strata, triasic oolitic metamorphic strata, etc., meaning that the strata were respectively deposited prior to the Cambrian, and during the triasic, but reduced to their metamorphic condition by forces acting during the carboniferous epoch in the first case, and the oolitic in the second. The same principle of nomenclature he has also proposed for Plutonic or massive crystalline rocks, and for volcanic rocks, so that there may be Ante-Cambrian Plutonic, Silurian Plutonic, carboniferous Plutonic, triasic, oolitic, cretaceous Plutonic, etc.; and, in like manner, Silurian volcanic, carboniferous volcanic, triasic, etc., up to the volcanic rocks still forming. Though it may be difficult in some, and indeed in very many cases, to determine with certainty the actual epoch of the original condition, or of the metamorphic change, of the crystalline schists, and also of the upheaving and apparent partial eruption of the Plutonic rocks, or even of the eruptions of volcanic rocks, there cannot now be a doubt that the idea conveyed by the proposed nomenclature is correct, and it has therefore been followed in the tabular view of the formations: the doubtful theoretical question as to the true character of granite and similar rocks still remains unanswered, and it is the opinion of Keilhau that they are only the more advanced results of a still more prolonged metamorphic action.

Below all the fossiliferous strata hitherto studied, metamorphic schists have been discovered, and it is therefore evident that rocks were worn, and sediments formed into strata, prior to the strata which now exhibit in their organic relics proofs of a living organization; but it cannot be authoritatively said that there were no living creatures during the epoch when these lower metamorphic rocks were deposited, for the argument once adduced from the universality of metamorphic rocks, and the absence of fossils in them, must be abandoned; as many such rocks have been shown, almost to critical demonstration, to be coeval with or posterior to fossiliferous strata; whilst the similarity of arrangement in the metamorphic and unchanged strata, as to the alternation of siliceous, argillaceous, and calcareous strata, goes far to support the opinion that the first traces of organic creation in this earth are lost in the deep darkness of geological epochs anterior to the Silurian and Cambrian, the records of which have been sealed up for ever by metamorphic action.

The figure of the earth is an oblate spheroid, being the figure which a liquid body exposed to the conjoint action of gravity and a rotatory impulse would assume: in this figure then there is primary evidence of its original fluidity. That the cause of this original fluidity was heat, is deduced from an examination of the temperature of the earth's crust at great depths, in which the temperature is found to increase on descending, proving that there is yet a vast reservoir of central heat. From numerous observations made in mines and by Artesian wells in France, England, Prussia, Russia, and elsewhere, Leonhard states that the temperature increases by 1° Réaumur, or 2¼° Fahrenheit, in 120 feet. M. Reich considers the temperature in the mines of Saxony to increase 1° centigrade in 41·84 m. of depth, or 1⅘° Fahrenheit, in 135 feet. In a boring in the Military School at Paris, the increase was found to be 1 centigrade, or 1⅘° Fahrenheit, for about 96 feet. In Mr. Fox's experiments in Cornwall, the increase was found to be about 1° in 47′; in those of Mr. Oldham, in the copper mines of Knockmahon, county of Waterford, 1° 82′, being a lower rate of increase than that of previous inquirers. It may be therefore assumed as a reasonable approxima-

tion, though subject to many variations from the different conducting powers of different strata, that the temperature increases 1° Fahrenheit in 60 feet of depth; and if the rate of increase were considered constant, there would, at 60,000 feet, be a temperature of 1000° or that of low red heat; but as the temperature will increase with the depth in an augmenting ratio, Leonhard assumes that this temperature would be attained at about 35,000 feet, being a depth only double the height of Cotopaxi, the most remarkable of the Peruvian volcanoes. Descending still lower, the temperature, at a very moderate depth compared with the magnitude of the earth, would be found sufficient to retain the mineral matter in a state of fusion; and it is therefore unnecessary to suppose a great depth when seeking for the source of lava still pouring out in so many parts of the earth. The similarity of lava, wherever found, and the close agreement as to composition and physical characters of the basalt of ancient epochs and of that still bursting through and intersecting the walls of modern volcanoes, are further proofs that a common origin must be ascribed to all such eruptions, and that they are due, as well as the accompanying physical phenomena of earthquakes, to forces acting on the still liquid portion of the earth. The phenomena of thermal springs are also, in part, connected with this high temperature; and the greater mean density of the earth, which is nearly double that of the substance of its crust, is most probably related to its liquid condition. The proximate cause of this internal heat can be only conjectured, but, whether it be due to electricity or to chemical action, the fact of its existence still remains incontrovertible.

Some other facts have been thought irreconcilable with the theory of internal heat, as, for example, in the iron mines of Dannemora, in Sweden, large masses of ice are found. In the mines of Ehrenfriedersdorf, in the Erzgebirge, this is called perennial ice; and, in like manner, at the millstone quarries of Nieder Mendig, near Andernach, on the Rhine, the ice is constant, during even the hottest months of the year. Such facts as these, M. Reich, of Freiberg, has shown to be the consequence of peculiar local circumstances, arising out of the mode of working adopted at these mines. Vast cavities are formed far removed from the external surface and air, and downward currents of air are produced, which cause a rush of the cold external air towards these reservoirs of more rarefied air. Between 1790 and 1800, the ice in these depths was from 20 to 60 feet thick. Again, in examining the temperature of the lower depths of the sea, and in large lakes, it is found to decrease and not to increase with the depth. Under the Equator, the temperature of the air and surface-water being 31° centigrade, 88° Fahrenheit, Péron found the temperature of the sea—

At 390 mèt., or 1256 feet = 9·4° cent., or 49° Fah.
At 700 mèt., or 2254 feet = 7·5° cent., or 45½° Fah.

Captain Sabine, on the 13th November, 1822, in north lat. 20½°, the temperature of the surface of the sea being 83°, found, at 7187 feet, or 1½ mile, the temperature 45½°. At 67° north lat., the temperature of the air being 48°, the temperature of the sea at 4576 feet was only 26°. In the lakes of Switzerland, varying in depth from 160 to 960 feet, Saussure found that when the temperature of the surface varied from 68° to 77°, that of the bottom varied only from 39½° to 44½°; but both these classes of facts are easily explained on the well-known properties of cooling water, which, as the temperature decreases, becomes more dense up to 39°, when it begins to dilate, in consequence of the commencement of a crystalline arrangement in its particles. It is thus that the cooled water naturally arranges itself below, and, circulating from the Pole to the Equator, tends to keep up a temperature in the sea-bottom at most not greater than would be the mean temperature of the earth at that locality, but in many cases considerably lower; and, in like manner, the cold water proceeding from the melting glaciers of Switzerland forms a similar stratum of

low temperature at the bottom of the lakes, the low conducting power of fluids rendering the passage of heat downwards very slow.

Admitting then the original igneous fluidity of the earth, and its gradual cooling from the crust downwards, it has been demonstrated by Fourier—

1. That the cooling of the earth, and the increase of temperature in proportion to the depth below the surface, has been much greater formerly than it now is.

2. That more than 30,000 years will be required to lessen by one-half, the present rate of increase of temperature; that is, to reduce the increase to $\frac{1}{2}°$ in 60 feet.

3. That the effect of central heat is now scarcely perceptible on the surface, not raising the thermometer $\frac{1}{17}°$.

4. That for nearly 2000 years this effect has not diminished by $\frac{1}{20}°$, and that we therefore see in this, as in all the great phenomena of the universe, a marked character of stability.

The earth thus cooling down must have finally attained a temperature at its surface lower than that of boiling water, and have become, in consequence, invested with a thin film of that fluid; but with the formation of a solid crust would commence disturbances and cracks, giving rise to inequalities on the surface, and thus elevating some portions of it above the circumambient liquid. At the same time, wear would begin to operate, and all these causes continuing to act, the first exposed portions may have been rapidly worn away, and sedimentary deposits formed, to be again upheaved by subsequent disturbances. In this manner the processes of wear and formation may have proceeded, until an epoch had been attained when the temperature of the earth, at some portion of its exposed surface, was sufficiently low for the conditions of organic life such as they have been exhibited in our mundane system; and if the same general physical relations of the earth then existed, that portion may be supposed to have been a Polar one, the order of formations advancing from the Poles to the Equator in proportion as the decrease of temperature extended itself. But as some of the earlier sedimentary deposits which had supported organic structures have probably, as before stated, undergone metamorphic change, and as such change recurs again at successive epochs, rendering it difficult to determine the exact zoological relations of such strata, it seems, for practical purposes, desirable to consider the metamorphic and Plutonic rocks by themselves. As rocks, they have already been noticed (page 90), and it is only necessary therefore to point out their practical bearings on the subject.

It is in rocks, more or less metamorphic, that the varieties of clay-slate, called roofing slate, must be sought, and this physical condition is therefore a guide to the Engineer in his search for them: in a country of merely sedimentary character, he need not look for them, as their peculiarities and value are due to metamorphic action. It has been stated that the lesser cleavage of the slate is usually transverse to that of the dip of the beds, and the Engineer may therefore, in examining a country, often determine on the probable value of the slaty beds by the presence or absence of this character; the planes of separation by cleavage being more regular and possessing a more even surface than those of stratification. For flagging, many varieties of the crystalline schists are excellent, the surface of stratification being sufficiently even, especially in the gneissose varieties of mica slate, and even in gneiss itself. They are also good stones for rough buildings, affording a flat bedding, and being very durable. In these three varieties of metamorphic schists there is a remarkable correspondence in the important physical character of specific gravity, the range in each being from about 2·6 to 3·1, the latter being the specific gravity of the more dense or indurated varieties, which frequently merge into hornblendic or greenstone schists. As road-stones, the latter only should be used, as other varieties speedily

break up and become mud. In selecting roofing slates, they ought to split thin and even, should not readily cleave into fragments, should not absorb much water, as, if so, they will speedily be disfigured with moss, and, by retaining moisture, induce dampness; and they should not be scaly. Though the dark-grey varieties are most approved, the silver-grey are usually the most durable. Some varieties of mica slate afford good roofing slates, though seldom so thin and even as those connected with less crystalline schists. The most important locality in the United Kingdom is Wales, but there are also very good slates in the south-west and in the south of Ireland, as in the island of Valentia, and some in the mica slate of the north of Ireland, though the latter are not equal to the true slates. Of foreign localities, that of Lehesten in the Thuringian Forest may be mentioned. In respect to the use of mica slate and gneiss in building, it may be observed as a caution, that in situations exposed to much wet, the gneiss, or highly gneissose varieties of mica slate, should be selected, as the finer-grained or more slaty varieties more rapidly disintegrate; but where the building or any of its parts are likely to be exposed to much heat, as in the sides of chimneys and fire-places, the true mica schist, or the fine-grained varieties, are preferable. The city of Freiberg is built of gneiss, and the pavement of its streets is of the same material.

Of the Plutonic and volcanic rocks, the most important are granite, syenite, porphyry, greenstone, basalt. Many varieties of granite are excellent building stones, and though expensive in working, are most valuable. Some of the most important public works of England, France, and Russia (Petersburg), are of this material. In selecting granite, it is right to avoid those varieties in which the constituent minerals are very small and the scales of mica superabundant, and, as a practical test, to notice the country immediately around the quarry, as the sandy varieties rapidly disintegrate into accumulations of micaceous sand. The Hayter or Dartmoor granite, the Aberdeen granite, the Kingston (Dublin) granite, some beds of the Mourne or county of Down granite, and the Guernsey or Channel Island granite, are well known for their excellence. In some of the quarries the bedding of the granite is more defined than in others, and wherever this is the case, or where marked cleavages or joints prevail, the working is much facilitated. Many old Egyptian works and statues were formed of granite, and it is still used for colossal works, as it takes a fine polish: for example, the great fountain-shell or vase before the Museum at Berlin, and the pedestal of the statue of Peter the Great at St. Petersburg, are of Northern granite, being made out of erratic blocks; and the splendid Scotch granite columns in the vestibule of the Fitzwilliam Museum at Cambridge are, from the brilliancy of their polish, beautiful examples of a recent application of this rock to the arts. Millstones are occasionally manufactured of granite. As a road-stone, those varieties which have at once a fine-grained and a close firm texture, should be preferred, as the large crystals of coarser granite are liable to cleave and break up. The specific gravity of granite varies from 2·5 to 2·6, which is very analogous to that of the metamorphic schists, a circumstance which gives additional weight to Keilhau's opinion that it is a metamorphic and not an eruptive rock. Syenite is even a firmer stone than granite, and its specific gravity ranges from 2·5 so high as 3·0, thus approximating it to greenstone. Many beautiful varieties of this rock are found in Ireland. In Dresden the syenite is hewn into regular parallelopiped blocks for paving, a purpose for which its durability and firmness peculiarly fit it; indeed as a road-stone generally it is excellent. Many ancient Eastern works were formed of it, and the Giant Pillar of Melibokus was fashioned out of one block.

Porphyry.—This term extends over a wide range of species, as it may be applied to any rock in which isolated crystals, usually of felspar, are imbedded in a distinct

paste. As a building stone, all those varieties having a soft argillaceous paste must be rejected, but there are many which afford good rough building stones, and also good road-stones, easily breaking into proper forms and sizes, binding well, keeping dry, and being tolerably free from dust,—a consideration too little attended to in the selection of road-stones. From the beauty of its colours, some varieties of this rock have been largely used for columns, monuments, and vases. The red, brown, black, and green antique porphyries are well known to the student of ancient art. In modern times, the most remarkable porphyry-works are at Elfdal, in Sweden, and Kolyvan, in Siberia. The Elfdal works have been established about sixty years, amidst wooded mountains, and in a wild country. The blocks are worked into form, and polished, by well-adjusted machinery; and most beautiful works of art, in columns, vases, chimney-ornaments, and tables, are turned out, rivalling the rosso-antico, or ancient red porphyry. A magnificent vase of this porphyry, at the country palace of Johannsthal, is 10 feet high, and at its summit 16 feet in diameter: it rests on a base of granite. The principal depôt of this manufacture is Stockholm. From the workshops of Kolyvan, in Siberia, equally beautiful specimens of art are produced, and in large quantities forwarded to Petersburg. The blocks are sometimes of great size, 300 men being employed to draw a single block. Some of the porphyries of Hungary resemble the grey porphyry, the mordiglione of Roman artists. The specific gravity of porphyry varies from 2·4 to 2·6, and it may be observed that the beautiful polish it takes is a principal cause of its extreme durability, many works formed of it remaining uninjured for ages amongst the ruins surrounding them.

Greenstone.—The specific gravity of this rock ranges from 2·7 to 3·0, and though its extreme hardness, and the difficulty of cleaving it without splinters, render it less fitted for regular buildings, it may be used with advantage as a rough building stone, and for a road-stone is excellent. The porfido verde-antico, or green porphyry of the ancients, noticed under porphyry, is a greenstone porphyry, the base being greenstone, with white and green isolated crystals of felspar. The Corsican globe-rock is a compact greenstone with globular concretions.

Basalt.—This rock, so remakable for the columnar structure which is so beautifully exhibited by many of its beds, as at Staffa and the Giant's Causeway, has a high specific gravity, varying from 2·8 to 3·1. The hardness of its more dense varieties is very great, and hence difficulty in using it for squared work; but for rough building, and especially for walls exposed to much wear, particularly from the action of the sea, it is excellent. For paving stones it would also be admirable, were it not for the surface becoming polished and slippery; but as a road-stone it cannot be excelled, making at once a firm, durable, and dry road.

The trachytic or felspathic lavas, and the various other products of ancient and modern volcanoes, naturally come into this section; but from their rarity in the districts likely to be visited by our Corps, require a little practical illustration. In the county of Antrim, largely, and in the county of Down, in small quantity, trachytic porphyry has been found, assuming in Antrim a columnar structure. It appears also to be a product of the volcanic districts of New Zealand. It forms a handsome and durable building stone. Other lava products, such as tufa, the Romans used extensively, as is observed in the ruins of Pompeii: when porous, they are very light, and may therefore be often applied with advantage where lightness combined with strength is of importance. Walls constructed with materials so absorbent will be found dry.

Ophiolite or *Serpentine.*—The mineral 'serpentine,' which name is extended to a massive and comparatively impure rock, is a bisilicate of magnesia, and has been well known from the earliest times. In all parts of the world, some of its varieties

have been used in the formation of images for idol worship, and in the manufacture of vases, columns, pipes, etc. The rich green and bronze tints of its finer varieties, and the high polish of which they are susceptible, render this stone highly ornamental and valuable, and it is still extensively worked. When veining carbonate of lime, it becomes the ophicalce of Brongniart; when porphyritic, it is his ophite.

Limestone.—The mode of association of limestone with the metamorphic rocks is very interesting and remarkable, and deserves especial attention. It is found interstratified with mica and other schists, in layers varying in thickness from a mere film to several feet, and yet partaking in the metamorphic change, as proved by its highly crystalline structure. When the crystals are not of too large size, it becomes a granular marble, and when veined, as in the county of Galway, with green serpentine, forms a verde-antico. Such marbles as these, including the finest statuary marble, were formerly all called primitive limestones; but it is now known that they are of various ages, the marble here noticed, and that of Donegal, belonging to metamorphic rocks of a remote epoch, prior at least to the carboniferous system, whereas that of Carrara is comparatively recent. In metamorphic districts, such as the mica schist country of Derry, Donegal, Scotland, etc., this limestone becomes a resource for lime; and it is impossible to notice its mode of distribution and the narrow scale of its development, as compared with the mountain limestone of the carboniferous and the chalk of the cretaceous systems, without perceiving that the argillaceous or muddy strata have much predominated in the earlier epochs.

Metallic Deposits.—It is right to notice that the plutonic and metamorphic rocks are the great depôts of metallic ores.

Iron.—The ore from which English iron is obtained is not connected with metamorphic strata, and will be noticed in its proper place. The celebrated Swedish iron is obtained from the magnetic iron ore connected with rocks of this class. In Taberg, in Smoland, this ore sometimes forms mountain masses. At Dannemora, and various other places in Sweden, Norway, Russia, etc., it is in beds (Plate V. fig. 29), sometimes alternating with the metamorphic strata, and it has also been found associated with Plutonic and volcanic rocks, as with basalt. The fer oligiste, specular or Elba iron ore, sometimes replaces mica in mica schist, and is associated with adularia at St. Gothard. The peroxide of iron also forms veins and beds in this class of rocks, but it is also, as well as the other ores of iron, found in other classes of deposits.

Manganese.—The peroxide has been found in this class of rocks, but in a practical sense this metal belongs rather to the sedimentary deposits.

Copper.—Copper pyrites, or bisulphuret of copper and iron, the most important of copper ores, occurs principally on the Continent in gneiss and mica schist; in Cornwall, and in the South of Ireland, in metamorphic schists, being varieties of clay slate; in the Hartz in similar strata (or the old grauwacke); and in Tuscany at the junction of serpentine trap (Gabbro) with the tertiary strata. This mineral occurs also in the zechstein, magnesian limestone, or Permian Formation, in the bituminous or copper schist (kupferschiefer). In the Oural mountains, in Siberia, the double sulphuret of iron and copper is rare, but the simple sulphuret of copper replaces it, the strata being probably sedimentary: this ore occurs also in the porphyritic district of Tyrone. The other ores of copper do not here require a practical notice.

Lead.—Galena, or bisulphuret of lead, occurs in plutonic, metamorphic, and fossiliferous sedimentary deposits.

Silver.—Bisulphuret of silver, the most important of its ores, has been found in gneiss and mica schist and in their associated limestone, in greenstone slate, clay slate, syenite, and porphyritic greenstone. It extends up to the zechstein; but it should be here observed, that in some of these cases, as in Mexico and Peru, the veins run

from the metamorphic to ordinary sedimentary deposits, and have therefore been manifestly connected with the cause of metamorphic action.

Tin.—Binoxide (deutoxide) is the most important ore. In Cornwall, the great source of British tin, and the most important one of the world, the ore occurs in granite, and also in killas, a partially metamorphic schist. In other parts of the world, it is either in granite, in metamorphic schists, or in porphyry, or porphyritic schists of the secondary class,—conforming thus to the general rule as to the influence of metamorphic action.

Mercury belongs especially to the primary and secondary class, though found rarely in mica schist or the crystalline metamorphic rocks, and in Haute-Vienne dispersed in globules in granite. The rich ore of mercury, cinnabar, of Almaden in Spain, is in the grauwacke (primary) strata, and has been worked for ages.

Zinc.—Bisulphuret, usually associated with bisulphuret of lead. The carbonate belongs to various mineral deposits, extending even to the tertiary class.

Antimony.—Bisulphuret of antimony is rare, and found in veins traversing granite, gneiss, and mica schist.

Molybdena.—The bisulphuret is found generally, in small masses, in granite and mica schist, and occasionally associated, though sparingly, with ores of tin, as in Cornwall, etc., and still more rarely with copper pyrites, as in Norway.

Gold.—This precious metal has been found in Brazil disseminated in considerable quantity in quartzose and chloritic rocks, which must be considered as belonging to the metamorphic system; and it is most probably from the decomposition of these rocks that the auriferous sands, containing also platinum and diamonds, are derived. Gold has been found in other places in veins traversing metamorphic rocks; and it is without doubt from such rocks that the Wicklow gold sands have proceeded; and generally it may be stated that the far greater proportion of gold is obtained from such sands. The great sources of gold are now California and Australia.

Platinum.—Found associated with gold in the auriferous sands of Brazil; in Russia, in the Oural mountains; and lately a discovery of it has been announced in France.

This general occurrence of metallic ores in rocks which have undergone a metamorphic change, though at very various epochs, their occurrence in veins, and the observations of Mr. Fox as to mineral veins conducting electricity, as well as the fact that metals and minerals are developed near the contact of highly metamorphic strata, so forcibly stated by Keilhau, point strongly to an electric cause for their production, or rather their presence under such circumstances.

The arrangement of metals in veins may be illustrated by the mineral 'idocrase,' as stated by Leonhard. This mineral resembles in composition the garnets, being a silicate of alumina, lime, and iron. At Auerbach, in Hesse, the gneiss is traversed by powerful veins of granular limestone, and just along the lines of contact, between the gneiss and limestone, idocrase occurs in considerable quantity in one of the veins (Plate V. fig. 27), penetrating the limestone in such a manner that two distinct bands are formed, one on each side of the vein,—a phenomenon which can scarcely be explained on any other hypothesis than that of elective affinity, induced by electric action. In the tin mines of Cornwall, opened for many centuries, the rock is traversed in various directions by veins composed of quartz, tourmalin, and tin ore. The veins do not exceed 6 inches in thickness, unite in crossing, and augment in richness with the depth. The wildness of the scenes of these deposits, and the nature of the works, are exhibited in Plate V. fig. 28, which represents the mine of Carclaze, near St. Austell, which is a vast gulf, more than half a league round, the granite being much decomposed, and the felspar transformed to kaolin.

Veins.—As the term vein occurs frequently in this section, it is desirable to give a clear idea of its meaning. The word itself conveys an idea which at once distinguishes it from dykes, as it implies a waving rather than a rectilineal course; but in reality this distinction is not always preserved, as many veins are rectilinear. Veins may however be viewed in two lights; namely, those which are unconnected with any great extraneous mass of matter, originating in and confined to the rock in which they occur, and those which seem to arise from and to be connected with some great extraneous mass. The first class may be found in all rocks, are often so fine as to be quite capillary, and frequently intersect each other, forming a complete network: they are considered veins of segregation, having been probably cracks into which the crystalline matter filling them has been gradually separated from the surrounding mass. They are composed sometimes of quartz and sometimes of carbonate of lime. The other class of veins is often connected with large masses of external rock, the matter of which is identical with that of the veins; and it has therefore been very generally assumed that such veins are veins of intrusion, although a different opinion has been promulgated by Keilhau, who considers them only as an advanced product of metamorphic action. In Plate II. fig. 6 represents a porphyritic vein traversing the clay slate of Cornwall, at St. Agnes; it is tortuous and uneven, and might be readily supposed to originate in the rending of the mass under the pressure of the force which injected the porphyritic matter into it. In Plate II. fig. 3, a portion of the granite of Greiffenstein in the Erzgebirge is represented. This granite seems from the regularity of its beds to be stratified, and weathers, like some portions of the granite of the county of Down, into columnar aggregations, which look as if they had been heaped up by man. It is supposed that there were several distinct elevations of this granite, the highest rising about 100 feet above the gneiss, fragments of which, as exhibited in the figure, are immersed in the granite, and therefore illustrate a similar phenomenon in veins. Where metallic veins pass through various strata, including the sedimentary, they have most probably originated in cracks consequent on the disturbing movements beyond their limits, and have been filled partly by segregation, modified as to its results by electric currents, and partly by sublimation. Some of these veins are of great magnitude, an example of which may be cited in the great ironstone vein of the red mountain near Schwarzenberg, which is between 40 and 50 feet thick, and stretching partly along the boundary between the granite and gneiss, and partly in the gneiss itself, has been followed for more than 20,000 feet.

FOSSILIFEROUS DEPOSITS.

EARLIEST KNOWN, OR CAMBRIAN.

This term has been applied by Professor Sedgwick to the stratified rocks which occur, as in Cumberland, North Wales, and other places, for the most part slaty, and without fossils, under the decidedly Silurian strata. They contain but a small proportion of lime, and their fossils are local and rare; nor as yet has sufficient evidence been obtained to constitute a zoological order distinct from that of the Silurian. The apparent thickness of the slaty and gritty beds is considerable, but it is highly probable that they are repeated by contortions. The prevalence of the slaty character shows that the progress of formation has not been varied by much original disturbance, and the depth of its beds indicates the probability of some portion having been a deep-sea, or rather semi-pelagic deposit. Professor Sedgwick considers the Lower Silurian to belong to the Cambrian group.

SILURIAN.

This formation, since the publication of the splendid work of Murchison, has attracted the marked attention of geologists, and is indeed one of the most remarkable, as exhibiting the relics of organic beings in great abundance, and of very peculiar forms. It has been rescued from the formerly obscure regions of the grauwacke, and reduced to light and order by the discoveries and research of Sir R. Murchison and his followers. The lower group of this Order includes the Llandeilo flags, and above them the Caradoc sandstone, the former being micaceous, slaty grits. The next in order, ascending, is the Wenlock group, consisting of a deep bed of shale, surmounted by a bed of limestone; and the third or upper, the Ludlow, comprising the lower Ludlow shale, the Aymestry limestone, and the upper Ludlow, a calcareous grit or sandstone. As in England these groups have been found in actual sequence of superposition, they must be there admitted as distinct in order of time. But it must not be supposed that in every other region the same precise mineral sequence is exhibited, for such would be contrary to the ordinary laws of geological deposit. In Norway and Sweden there is a similarity in lithological character, and the conditions or deposit may have been nearly the same; but in many parts of North America the limestone has been developed much more extensively, and exhibits therefore a different condition of deposit.

In this formation, the first, if we combine with it in a zoological sense the Cambrian, in which we are enabled to contemplate the earth in its most attractive form as the theatre of life, there are remains of fish, strange in form, as the genera onchus, plectrodus, but high in organization; many mollusca, including peculiar forms of the brachiopoda and cephalopoda; crustacea, highly curious and characteristic, belonging to the extensive family of trilobites, which, beginning to exist at this early epoch, at once flourished in number, both of species and individuals, and then rapidly passed away, the family being traced no further than the carboniferous Order; radiata, rare; zoophyta, less abundant than in succeeding Orders, but exhibiting some peculiar forms. In respect to the conditions of deposit, it may be observed, that though the extensive limestone deposits of this epoch, adjacent to the great lakes of America, were probably pelagic, the large orthoceræ having been well suited for deep seas, the general evidence afforded by the fossils of England and Ireland, particularly by the trilobites, the flat brachiopoda, as orthis, leptæna, lingula, &c., the many species of nucula, and even it may be added by the fish, as they were probably fitted to grovel in the mud, is in favour of muddy and sandy deposits in moderate and sometimes shallow depths; and the beds of limestone have probably commenced here, as in the similar instances of the carboniferous system, and even of the recent epoch, by an accumulation of the remains of testacea, the temporary cessation of the influx of mud, and the growth of corals suited to such habitats.

Perhaps no region can be appealed to for information on this subject with more confidence than the small but beautiful Silurian deposit of the County of Tyrone (parish of Desertcreat), since the perfect preservation of so many species, including those of many of the most interesting genera of trilobites, indicates that they are there found in the place of their actual habitation. Of the trilobites, there are Norwegian, American, and English species, the genera ampyx, trinucleus, phacops, calymene, harpes, brontes, isotelus, asaphus, illænus, being all represented in the most beautiful manner, and accompanied by a new and most remarkable genus, the remopleurides (Porlk). The multitude of these fossils, particularly of the genus trinucleus, so delicate in its form and structure, and their association with a great number of shells of the genus nucula, leave little doubt that they lived and died in a compa-

ratively shallow deposit, which, from the nature of the gritty micaceous schist, was probably formed in an estuary.

It would be impossible to bring forward all the peculiarities of the many remarkable fossils of this formation, without entering largely into their natural history; nor in the present case is it necessary to state what fossils have been considered to characterize the subdivisions or groups of the formation: it is enough in a practical point of view to be able to recognize the existence of the formation itself; and this is of much practical importance, as its appearance at once ensures to the Engineer evidence that he is below the great carboniferous system on the one hand, whilst on the other he may expect to discover below him a series of metamorphic rocks embracing the useful deposits of various descriptions of slate and other building stones. The fossils, which have not hitherto been discovered in any more recent deposit, excepting in some instances the doubtful Devonian, are graptolites, which are curious zoophytes, supposed to be related to the pennatula; the chain coral, catenifera escharoides; the genera remopleurides, phacops, calymene, asaphus, ampyx, trinucleus, harpes, brontes, and several others of trilobites; of the brachiopoda, the genus pentamerus; and of the cephalopoda, the genera phragmoceras and lituites.

It may be added, in a practical point of view, that many of the schistose beds of this formation afford good flags and slates.

Besides the localities of Europe and America, the formation has been noticed at the Falkland Islands and in Bolivia.

DEVONIAN, OR OLD RED SANDSTONE.

This Order, so long known under the name Old Red Sandstone—a term nearly as obscure as that of Grauwacke,—has been recently, by the researches of Professor Sedgwick and Sir R. I. Murchison, aided by the scientific labours of Sir H. De la Beche and Messrs. Phillips and Lonsdale, raised to the rank of a distinct fossiliferous formation. Viewed as sandstone and conglomerate, in the light of a drift, it appeared difficult to connect with it the limestone of Devonshire; but when it was shown that similar limestones occurred on the Continent in similar positions, and that the limestones of the Eifel were so placed, this difficulty was removed, and the formation was found to embrace the usual assemblage of argillaceous, sandy, and calcareous strata. In Scotland, and on the borders of Wales, the formation is exhibited in its original character of a red sandstone and conglomerate with shale and marl; the conglomerate and sandstone at the top, the variegated marls and impure concretionary limestone (cornstone) in the centre, and variegated micaceous or quartzose sandstone (splitting into tiles, tilestone,) below. In the lower division, in the North of Scotland, many peculiar forms of fishes have been found, whilst in the upper, comprising the belt of yellow sandstone, the genus holoptychus appears, which extends into the carboniferous Order. Were this portion of the system alone studied, it would lead to its connection with the carboniferous rather than with the Silurian, and it is still so placed by Cotta; but when the Devonshire and Cornwall strata are examined, and compared with those of the Eifel, the presence of species common to the Devon and Silurian on the one hand, and to the Devon and carboniferous on the other, impress upon them a different character. Professor Phillips has, in consequence of this mixed distribution of fossils, proposed to embrace under the general term palæozoic, the Cambrian and Silurian as the lower palæozoic, the Devonian, as the middle palæozoic, and the carboniferous as the upper palæozoic. Of 275 species examined by him in the Devonian strata of Devon and Cornwall, he states that 25 have been found in the lower division in England, 51 in the upper division in England, and 57 in the Eifel and Bensberg.

That this arrangement will require some modification hereafter, there cannot be a doubt, as new discoveries progress; and it is desirable, in further comparisons, to keep in view the very dilapidated condition of many of the fossils examined, as leading to the belief that they were only present in the deposit by the influence of drift. The trilobites being amongst the most distinguishing bodies of the Silurian epoch, it is curious to observe that almost every specimen described by Professor Phillips is in a shattered state. Of those which can be in any manner identified, it may be observed, that the genus harpes has been shown to exist in the Silurian (see Report on Geology of Derry and Tyrone); the genus brontes has also occurred again in that formation in Ireland; there is a true calymene, fig. 247 of Phillips; a specimen belonging to the group which embraces the genera asaphus, isotelus, illænus, fig. 252; a phacops, fig. 249 *b*; probably a remopleurides, fig. 250 *e*; and the thoracic portion and pygidium, 250 *a* and *b*, which ought not to be connected with the cephalo-thorax supposed to belong to it, are portions of a calymene; whilst the specimens figured in 248 are probably carboniferous trilobites. On the whole, then, considering that these fossils, and many of the zoophytes, etc., are present merely from drift, it is not impossible that they were living in greater abundance elsewhere at the time of the deposition of the Devonian strata, and that the actual zoological relations were closer between the Silurian and the lower Devonian, than would be inferred from these fragments of fossils alone; indeed, the analogy between the lower Devonian and the Silurian is considerable, whilst a similar analogy prevails between the upper Devonian and the carboniferous. Cotta still classes the Eifel beds with the Silurian; but it cannot be doubted that if Silurian, they occupy a higher position in the series than any of our English or Irish beds, and must therefore be parallel, as shown by our English authors, with the lower Devonian.

In referring to this use of fossil evidence, it is well to bear in mind, that any fossil species of an early epoch may be continued upwards into more recent formations, and that the appearance of a small number of such fossils cannot therefore be considered sufficient to determine the age of the strata containing them: it is in the general grouping and arrangement, under the same petrographic conditions, that confidence can be placed. The appearance, on the contrary, in any bed, of fossils known to be abundant in, and characteristic of, a recent formation, must always be sufficient to decide against its antiquity.

Practically, many beds of this formation, especially of the yellow sandstone, are excellent building stones; whilst the decomposition of its marly beds produces a rich, productive soil. The limestones are valuable both for building stone and lime. It has been shown by Messrs. Murchison and Verneuil that in Russia, south of Petersburg, a large area, formerly supposed to belong to the new red sandstone, is of this geological age, though abounding in saliferous and gypseous beds. This identification has been made from an examination of the fishes or ichthyolites; and in noticing it, the remarkable fact should not be overlooked, that salt deposits have, in very similar circumstances, been formed at various geological epochs. It need not be urged how important the determination of this formation is, in estimating the probability of finding coal; for example, it had been stated that a conglomerate of the Ionian Islands belonged to the old red sandstone, and that some thin beds of lignite appearing in superjacent strata were of the carboniferous epoch, such a statement necessarily raising much false hope of finding productive beds of coal; whereas the conglomerate is tertiary, and the lignites of the same class.

CARBONIFEROUS.

This formation, the most important of all in its economic characters, is a vast

assemblage of calcareous, arenaceous, and argillaceous strata. If it be considered that the great masses of limestone were formed in deep seas, whilst the coal shales were formed in estuaries, and, in some cases, in lakes, it is evident that where the limestone division prevails, the shales may be expected to diminish, and to lose their estuary character, so that coal will become less abundant. This is the case in Ireland, and accounts for the comparative scarcity of coal in that country.

The great limestone deposit which forms the basis of this system has been called the mountain limestone, and is characterized by many peculiar fossils. In the South-west of England, in Somersetshire and South Wales, this limestone is strongly marked, and is separated from the coal measures above by a thick deposit of arenaceous strata; but in the North of England, the coal descends into the millstone grit, and even alternates with the upper beds of the mountain limestone; and in Scotland, this mixture of marine strata with those containing coal is still more marked. In Ireland, many of the masses which constitute the mountain limestone are also separated into distinct beds by shale; but as coal does not occur in the layers of shale, they may have been deposited in a tolerably deep sea, whilst in other instances they were doubtless of estuary formation. It is thus that in the Mediterranean much of the coral living at the bottom of its waters is subject to be covered over by the mud moved along by the currents.

The presence not merely of a vast variety of terrestrial plants in the coal shales and grits, but in some cases of fresh-water fossils, such as the genus cypris, led to the belief that some of them had been lacustrine, but whether formed in actual lakes, or at the mouths of rivers occasionally dammed up, and formed temporarily into fresh-water lakes, cannot be determined. The fossils of this formation are very characteristic, and a few will be figured to guide the Engineer in determining the probability of having at any time discovered it. In the plants, so rich in various forms, resembling the tree-ferns of the tropics, there is evidence of a climate resembling that of our most southern regions, and this is confirmed by the great abundance of sauroid fishes, and of cartilaginous fishes of the families of squalidæ and raiidæ. The crinoids are largely developed, and the corals are rich, many of them being lamelliferous, as in the case with those now forming coral reefs; and it is peculiarly necessary, in studying this formation zoologically, to keep in view the difference of habitat of corals, many of which are confined to reefs, whilst others live in shallow water on the coast, and are frequently enveloped in mud.

That coal is the product of ancient vegetation entombed in mud and sand, and in the course of ages altered to its present state by gradual chemical change, cannot be doubted; but whilst some maintain that the plants have grown where the coal now exists, others have considered it to have been formed of plants washed down into estuaries, and there accumulated, whilst again a third party has advanced the idea, and endeavoured to support it by microscopic investigation, that the coal resembles the product of a bog or peat moss. It is highly probable that each of these opinions is correct in certain localities; but in either case, the alternations which must have taken place are very remarkable. Mr. Phillips, for example, states that in the North of England, the total thickness of the coal-bearing strata may be estimated at 3000 feet, whereas the coal itself is separated into nearly thirty seams, the whole thickness of which does not exceed 60 feet; the thickness of the seams being very variable, from a few inches to many feet, though rarely exceeding 20 or 30 feet. At Dombrowa, in Russian Poland, there is a seam 42 feet thick, which has been traced continuously for 7000 feet in length. Taking all the minute seams into account, the total number in the Newcastle district is forty; at Dudley there are eleven, one only being worked. In the coal district of Saxony, the seams vary from three to eight.

At Mons there are 115 workable seams, few however exceeding three feet in thickness. In Colebrooke Dale there are 135 seams, the total thickness of which is 500 feet. In the Département du Lot, it is said that a shaft has been sunk for 72 feet in a single seam, which is supposed by some to be 300 feet thick, but it is probable that this is either a deposit in a deep hollow, or that the seam has been thrown up, and is pierced in a longitudinal rather than a transverse direction, such as would be the case in working, from above, the seam represented in Plate VI. fig. 33.

The contemplation of such masses of vegetable matter, composed of plants long since passed away from the living world, of which more than 300 have been figured and described, 200 belonging to the order of ferns, and others to giant mosses and to cellular plants, leads to the recognition of peculiar conditions of organic life. It is true that some of these conditions have been repeated, though in a fainter degree, at subsequent epochs, and given rise to limited carbonaceous deposits; but as the progress of the various changes, physical and organic, working in the earth's crust, was directed towards the present state of things, an approximation to the conditions now observable, and a receding from those which once so greatly promoted the growth of succulent plants, are in strict accordance with the laws of nature. For example, as the influence of central heat diminished, successive portions of the earth may have become fitted, though in an inferior degree, for the support of such plants; and partial deposits have appeared at such epochs: nor should it be forgotten that when the Polar regions were first brought by the diminution of central heat to the proper temperature, they were, from the deficiency of solar heat, better fitted for such vegetation, the temperature being equable and unattended by the scorching effects of the sun's rays now felt in southern regions. Though the seams are sometimes extended over a wide space, the general character of the deposit is that of a basin, and nowhere is the phenomenon of faults more strikingly exhibited, the seams being sometimes thrown up or down several hundred feet. Plate IV. fig. 20, and Plate VI. fig. 34, illustrate this form of internal movement; and Plate VI. fig. 32 is a horizontal representation of the manner in which the seams are worked. Fig. 34 represents the mode of sinking the shaft, and also exhibits a remarkable form of contortion, the seam having been bent vertically upwards. Plate V. fig. 29 is a representation of the iron mines of Dannemora, from Leonhard, which, although the deposit is not of this date, may be used to illustrate generally this class of mining. The faults here described are sometimes accompanied or caused by dykes, but in other cases they are not so, and are in character dislocations, attended with slips. The knowledge of the various forms of such faults, and of the direction in which the suddenly lost seam should be sought, constitutes one of the most difficult points in mining science.

In Fuller's time (1661), 200,000 chaldrons were imported annually into London, but now the consumption is nearly 3,000,000 tons, which is brought into port in about 9700 ships. The annual quantity raised is estimated by Mr. Taylor at 15,500,000 tons, and Durham and Northumberland, he considers, could meet that demand for 1700 years to come.

Mr. Porter deduces from the French Mining Reports the following data:—

Coal is raised in thirty departments of France, in which 258 mines are in operation, and 21,913 workmen employed. In 1814, the quantity raised was 665,000 tons; in 1825, the quantity had doubled; in 1832, the produce was 1,600,000 tons; and in 1836, it amounted to 2,500,000.

Cotta (1839) states the amount of coal raised in the several coal districts of Europe as below; and the table will be useful in comparing one country with another in respect to this important element of wealth.

	Tons.
In England	20,769,231
Belgium	5,215,385
France	2,215,385
Prussia	1,569,231
Russia	738,461
Austria, with Bohemia	184,616
Bavaria	32,308
Saxony	28,616
Sweden and Norway	28,293
Hanover	21,646
Spain	18,462
Both Hesse	15,231
Sardinia	4,662
Weimar	1,939
Portugal	415
Total	30,843,881

The product of the British coal-fields is double that of all the rest of Europe; and there can be little doubt that the gross value of the collieries of Great Britain and Ireland cannot be estimated as less than £8,000,000 sterling.

But this is not the only valuable product of the formation. The argillaceous carbonate of iron, or clay ironstone, which is the principal ore of iron used in the British Isles, occurs in beds in the coal shales, the mineral ore and the fuel for smelting it being thus in close contiguity. In 1826, the quantity smelted into cast iron was between 600,000 and 700,000 tons; and as there had been a steady increment up to that time, which must have gone on during the last few years with at least an equal intensity, the present quantity cannot be estimated at less, stated in round numbers, than 1,000,000 tons of bar iron, being in value equivalent to £10,000,000 sterling. In France there are iron works in sixty out of the eighty-six departments. The number of establishments in 1836 was 894, and of workmen, 15,738, the product being 303,739 tons of pig iron, and 201,691 tons of bar iron, valued at £3,580,000.

The mountain limestone, which is the pelagic equivalent of the formation, is remarkable as exhibiting by its layers of siliceous or chert concretions a strong analogy to the subsequent pelagic deposit of the chalk; it is the source of much mineral wealth, producing more than one-half of the lead of England. The quantity cannot be assumed as less than 26,000 tons, equivalent to about £520,000 sterling; so that, from this formation alone, mineral wealth is annually produced in Great Britain to the amount of nearly £19,000,000 sterling, independent of the value of lime, marbles, and building stone of excellent quality, particularly that obtained from many of its grits,—as, for example, in the neighbourhood of Glasgow, the beauty of which city is due to the abundance of such excellent building materials.

If the mind passes from the consideration of the materials themselves to the contemplation of the vast results proceeding from coal and iron when used in the machinery of manufactories and railways, it discovers in the possession of so large and productive a portion of this formation, the source and foundation of the commercial, and, in consequence, of the political greatness of Great Britain. Can any one then hesitate to admit, that a science which enables the Engineer to trace out such a formation in other countries, by giving him a clue to its existence, must be a science of the utmost practical value?

In America there is an extensive coal formation, including both blind and bitumi-

nous coal, within the limits of the United States; likewise in Nova Scotia, at Picton, and Cape Breton. In Asia, China and Japan are supposed to possess extensive deposits, and both Africa and Australia have produced coal. Such then is the lateral distribution of this valuable mineral formation, and, as regards its position vertically, it is very variable, many of the seams at Newcastle being worked under the sea, whilst at Chipo, which rises above the plain of Santa Fe de Bogotá, it is found at 8000 feet above the sea, and at Huanoco at 12,800 feet, or at the limits of eternal snow.

PERMIAN, OR MAGNESIAN LIMESTONE.

As the mountain limestone is of great practical importance, being the basis of the carboniferous system, so is this formation, including its underlying red conglomerates and sandstones and marls, of similar importance, as immediately overlying the rocks of that great system. In the South-west of England, its strata are unconformable to those of the carboniferous system; but in the North-east they are conformable, and there seem to form part of that formation. In all formations, cases of this partial conformability between the upper and lower may be expected to occur, according as the disturbing movements are more or less extensive or local; and it was therefore necessary to determine the great geological divisions from a general and not from a partial examination.

In the lower red sandstone of this Order there is a strong resemblance to the upper, or distinctly new red sandstone, whilst in the fossils there is a close approximation to the carboniferous, the genera productus and spirifer of the brachiopoda occurring in each; and of fishes, the genus palæoniscus. This remarkable genus of fishes cannot however be said to go no higher than the magnesian limestone, as the sandstone and marly beds of Rhone Hill, in the county of Tyrone, in which the palæoniscus catopterus occurs in profusion, associated with posidonomya minuta, huddled together in a small patch or pool, appear to belong distinctly to the true new red sandstone. On the other hand, the spirifer undulatus (Sow.), supposed a characteristic species of the magnesian limestone, occurs in Ireland in beds which are overlaid by apparently carboniferous limestone; the well-known magnesian limestone of Holywood, near Belfast, has however been traced by Professor King into Tyrone, and it is therefore probable that some alteration may be necessary in the boundary between the Permian and triasic strata. On the Continent, the name "rothes todtliegendes" has been given to the lower red conglomerate, to distinguish it from the white grits which immediately underlie the kupferschiefer or copper slate, and which sometimes also contain copper ore, which the red-*dead*-lyer does not. In England, the copper slate and the white grit do not exist, and this lower red sandstone and conglomerate immediately underlie the magnesian limestone. Cotta places it in the carboniferous system, making the white grit the base of the magnesian limestone formation. In England, the formation in the South-west is principally composed of the drift or conglomerate beds, exhibiting however the peculiarity of a dolomitic or magnesian limestone paste as its basis. In the North-east it is characterized by a yellow magnesian limestone, passing upwards and downwards into marl slate and marl with gypsum. On the Continent, the zechstein, which is a dense but sometimes porous, grey, and generally fetid magnesian limestone, becomes complicated upwards with marls containing many extraneous substances, such as ironstone, gypsum, and rock salt. It is in the upper beds that the gypsum and rock salt prevail, being an approach to the character of the true new red. The county of Mansfeld is the richest locality of the formation, where the workable portion of the copper slate has a thickness varying only from 1½ ft. to 2 ft., and gives rise in numerous establish-

ments to one of the most difficult of mining operations, called there *krummhölzerarbeit*, or crooked-stick work, the miners crawling and working in low cavities, only 18 or 20 inches high, lying upon their sides and being supported by pieces of bent timber or crooked sticks. In England, the formation is practically valuable from the excellent building stone which some of the magnesia beds afford, the tint being specially favourable for Gothic buildings. York and Beverley Minsters exhibit favourable examples of the stone, but there is great difference as to durability, according as the more purely magnesian limestone or the gritty beds have been used. This stone has been selected for the New Palace of Westminster as the best building stone of England.

The occurrence of dolomite, or the compound carbonates of lime and magnesia, in so many localities associated with rocks of an igneous and even eruptive character, induced Von Buch to propose a peculiar theory, viz. that the magnesia had been introduced into the mass by sublimation, being one of the igneous phenomena manifested in the eruptive rocks. He did not mean that the contact with such rocks had caused the change, but that such contact explained the other phenomena by pointing to the proximate cause of both. In like manner, the porphyritic rocks, and even the amygdaloid, which are sometimes associated with the red-dead-lyers, and even cut through them, might be considered to indicate similar actions, and, in consequence, some have supposed the irregular surfaces of the magnesian limestone to be the result of such causes having induced a peculiar crystalline arrangement; but Dr. Daubeny explains these irregularities on the same principle as they are explained in the chalk and other calcareous rocks, by the action of water holding carbonic acid in solution; and, on the whole, the mode of formation of this peculiar rock must be yet considered doubtful. The class of reptiles once supposed to begin in this formation, has been carried back to the carboniferous, and probably even to the Devonian.

NEW RED SANDSTONE, OR TRIAS.

This formation, from the prevalence of a variegated character in its sandstones and marls, has been sometimes called "poikilitic." On the Continent, where its several members are better developed than in England, it has received the name of "trias," from the possibility of dividing it into three great and satisfactory sections. The lowest of these is the "bunter sandstein," or variegated sandstone, a red sandstone variegated by greenish stripes and spots, and containing clay galls; the sandstone being associated both above and below with variegated red and green marls, containing both laminated and fibrous gypsum, and rock salt. As the muschelkalk, or central division, is deficient in England, and gypsum and rock salt occur on the Continent in the marls, both in the upper and lower division, it is difficult to decide generally whether our salt-bearing strata belong to or should be separated from the more decided sandstones and conglomerates which underlie them. The white sandstone of the Vosges belongs to the lower division, or variegated sandstone; and wherever this freedom from the usual colour prevails, the grits become valuable building stones.

In Thuringia and Swabia the muschelkalk division is fully developed, the limestone under several forms or varieties alternating with marls and clays which sometimes contain gypsum and rock salt, and is occasionally dolomitic.

In the upper division, or keuper, marls and clay prevail, though still associated with sandstones. Gypsum and rock salt still occur, and sometimes an impure coal. As fossils are extremely rare in the sandstone divisions, it was scarcely possible to allocate to their proper place in this triple system the English beds; but the fossils of a dark marly stratum which occurs at Axmouth, and on the banks of the Severn

in Gloucestershire, and is called the bone-bed, have been proved to belong either to the keuper or muschelkalk: these are, Hybodus plicatilis, Saurichthys apicalis, Gyrolepis tenuistriatus, G. Albertii,—of which it is very remarkable that Saurichthys apicalis, Gyrolepis Albertii, G. tenuistriatus, have been also found in a seam of calcareous grit connected with black shale in an equally local deposit on the face of Ben Evenagh, at Lisnagrib, county of Derry, in connection with the Acrodus minimus, another muschelkalk fossil. It may therefore be reasonably inferred that though the muschelkalk is not fully developed in the British Islands, there are at least two members of the series, with a trace of the other.

As connected with this formation, the remarkable footprints of the Chirotherium should be noticed. Various conjectures as to the nature of this animal have been hazarded, but Mr. Owen has proved that they were formed by the animal called by him a Labyrinthodon, from the peculiarly complex structure of its teeth; and he has further proved that these creatures were batrachians, or gigantic frogs. The genus ammonite of the cephalopodous molluscs first appears here; and in the flora as well as fauna there is a striking difference from the underlying strata, the species of forty-seven genera noted by Professor Bronn being quite distinct.—*Footsteps of supposed Wading Birds observed in America.*

This formation in England is known as the depository of rock salt. In Cheshire, the alternating beds of red and green marl with gypsum and rock sometimes exceed 600 feet in thickness; and at Northwich, the two beds of salt are at least 60 feet in thickness, and extend laterally for 1½ miles. In Ireland, on the line between Belfast and Carrickfergus, a very extensive deposit of salt has been found. And generally the curious connection of the sulphate of lime with the chloride of sodium deserves attention, as affording a probable indication of the occurrence of salt in other formations. The average quantity of salt manufactured in Cheshire may be stated at about 250,000 tons annually. The celebrated salt-mines of Wieliczka, in Galicia, belong to the cretaceous formation.

LIAS ORDER.

This formation, in which argillaceous matter or clay preponderates, being associated with argillaceous limestone, marl, sandy marl, and sandstone, is remarkable as being the special locality for marine reptilia; the genus ichthyosaurus attaining its full development, and being accompanied by the equally singular genus plesiosaurus. The existence of a marine saurian amidst the Galapagos Islands, as noticed by Mr. Darwin, is highly interesting, as exemplifying the probable mode of existence and habits of these vast animals. That curious genus of cephalopodous molluscs, the belemnite, also first appears here, and the gryphæa, a genus of the family of oysters, is abundant; and the abundance of such animals proves the marine origin of the deposit, and confirms the fact that marine saurians were, at that early period, swimming in multitudes around the muddy shores of the then existing land. The characteristic colour of the limestone, which sometimes assumes a ribbon-like arrangement amongst the argillaceous beds, is blue, but there is occasionally a white variety, and in some instances sandstone prevails in the lower members; as for example, in Würtemberg, where sandstones of brownish and yellowish hues are associated with marls and limestones in the lower lias, the upper being composed of dark lias shale and limestone. The lias shale of Würtemberg is so rich in a species of the genus posidonomya, the P. Bronnii, that it is even called the posidonian shale; and this fact deserves notice, as the similar occurrence of that genus in shales of the carboniferous period and in marls of the new red, is highly illustrative of the general character of such deposits. Some thin beds of pitch coal occur also in the shales, which,

as well as the limestones, are strongly impregnated with bitumen, proceeding, it is very probable, from decomposing animals, such as fishes, etc., which abounded at the epoch of their deposition. Practically, the sandstones are sometimes sufficiently firm to be used for building, though they usually become iron-shot, or stained. The limestone is occasionally hydraulic, and the soil is generally fruitful.

OOLITE, OR JURA FORMATION.

The clays of the lias form the basis of the oolitic system, and in ascending into it, other argillaceous bands mark those changes in the conditions of deposit which are to be expected in every great formation, representing, as it must do, the variations of drift consequent on the changing direction of currents. These bands have, in England, led to a division of the oolites into lower oolite, resting on the lias; the middle oolite, resting on the Oxford clay, which separates it from the lower oolite; and the upper oolite, resting on the Kimmeridge clay, which is between it and the middle oolite: but it must be evident that such clay bands, being merely the result of local causes, cannot be expected to occur in all localities at the same time, or to produce a similar division in all countries. On the Continent the formation has been divided into the upper, middle, and lower Jura, the upper being characterized by a light-coloured, whitish, or yellowish limestone, which forms the great mass of the Jura Mountains, and has derived from them its name,—the lower divisions consisting of roe-stone and dolomite, of sandstone, marl, and clay. In the Jura limestone there are partings of hornstone, strongly resembling the flints of the chalk; and its surfaces exhibit also very beautiful dendritic markings of oxide of manganese, equally resembling those of the hardened chalk of Ireland; so that any one acquainted with the Irish chalk, in looking at this rock, first supposes it to be chalk. The Bavarian Jura formation is remarkable for the numerous bone caverns in its dolomites, and for the celebrated lithographic stone of Solenhofer. The wooded hills of Pappenheim are composed of a regularly stratified limestone arranged in thin and horizontal beds. The stone is extraordinarily pure and dense, yellow or grey in colour, and, from the thinness and regularity of its layers, peculiarly fitted for lithography. The hills themselves are distinguished by their broken aspect and wall-like character, which makes them look like so many fortresses; and on entering the valleys, the ringing sound of the proper lithographic stone, as it is broken up for use, is heard on all sides. The layers used for this purpose are from 1 to 4 inches thick, and when they are still thinner, or are unfit, by containing fossils, for lithography, they become useful as roofing tiles, as door and window linings, as tables, etc., to which purposes they had been extensively applied long before the invention of lithography. These peculiarities of the physical features of the country, and of the mechanical characters of the stone, deserve to be remembered in looking out for good lithographic stone in other countries. In addition to the defect consequent on the presence of large fossils, veins should be carefully avoided, as in printing they mark the drawing, however fine they may be, with white lines, and increase greatly the difficulty of bringing the surface of the stone to a uniform state. In the English oolites, the most remarkable is the Stonesfield slate, lying at the base of the great oolite, a member of the lower division: it is a slightly oolitic limestone, and though only 6 feet thick, abounds in fossils. Impressions of ferns and other terrestrial plants, the elytra of beetles, the remains of saurian genera already noticed, as well as those of the pterodactyl or flying lizard, occur, and what is more remarkable, the jaws of several species of mammiferous quadrupeds of the marsupial order,—partly allied to the opossum, and partly to the myrmecobius of Australia,—a singular analogy, at this early epoch, to a region now so widely distinct in its fauna from other parts of the world.

In the lower division is the Bath oolite, which affords such an excellent stone for the delicate mouldings of Gothic architecture, and is represented in France by the Caen stone, which is even better fitted for the purpose, and was in consequence imported by our early architects, as, for example, for the construction of the beautiful Temple Church. In the middle oolite is the "coral rag," so called from the continuous beds of corals of which it is composed, and which still retain the position in which they originally grew. In the upper oolite is the celebrated Portland stone, so well known for its beauty as a building stone.

Many parts of this system are distinguished in various countries by a profusion of some particular fossil which is always a characteristic of a regular deposit, as distinguished from a drift: such, for example, was the surface of the great oolite when studded over with pear-encrinites, which were afterwards buried by the irruption of the Bradford clay; the clays of the upper oolite with their oysters and gryphites (ostrea deltoidea and gryphæa virgula); the nerinæan limestone of the Jura, distinguished by a peculiar univalve genus nerinæa; and the diceras limestone of the Alps, so called from the abundance of the very curious bivalve genus diceras.

Although in this formation the fossils generally indicate a marine origin, the frequent occurrence of fragments of wood; the coal beds and bituminous shale which enter into the system; the many impressions of plants and insects; the abundance of saurians and of encrinites, which may be considered as more fitted for shallow than for deep waters; and, above all, the actual discovery of land animals, all concur in proving that the deposit was formed in the vicinity of land; and it becomes therefore an interesting precursor of the next formation, in which the evidence of land is further connected with that of a then existing lake.

WEALDEN FORMATION.

This formation, remarkable from the fresh-water origin of its deposits, is not entirely free from marine fossils, and presents therefore the character of an estuary rather that of an inland lake. On the Continent, it has been associated with the cretaceous system; and as the lower beds of green-sand correspond closely with some of those of this system, and in France the fresh-water beds are sometimes separated by marine beds, supposed to belong to the green-sand, this allocation may be possibly correct. In England however it is remarkable that the oolitic beds must have been first raised up quietly without any great disturbance, as the celebrated "dirt-bed" of Portland, with its upright roots, rests horizontally upon them, the roots even penetrating into the subjacent oolite, and that subsequently portions of the compound deposit were thrown out of the horizontal position, as appears in the section at Lulworth Cove. Assuming the principal basin, in which these beds have been traced, extending at each end from France into England, to have been continuous, the deposit must be very extensive, whether considered lacustrine or estuary, but of course it may have been much interrupted, and formations of a different character contemporaneously deposited within its area. Such problems are of very difficult solution, as it is almost impossible to bring back to the mind the actual condition of the earth's surface in respect to land, sea, and river, at each successive epoch of its history, darkened as it must be by the effects of reiterated changes and unceasing wear.

This vast estuary became subsequently exposed to the action of the sea, and the dry land on its margin and the islands within its precincts were covered by the marine deposits of the cretaceous epoch, some of which indicate a depression of the land sufficient to have allowed of deep-sea deposits. That this was the case, is proved by the remarkable denudation of the Weald, in which, the superincumbent strata of the chalk having been uplifted and broken by subterranean disturbance, and then

carried away by the denuding wave or current, the fresh-water strata of the Wealden have been exposed, and a remarkable valley or basin of the Wealden formed within the area of the greater estuary it originally occupied. A similar and somewhat parallel disturbance has also forced up the Wealden strata in the Isle of Wight. These undeniable proofs of disturbing forces assist the inquirer in understanding those which preceded them, as the facts not merely show that the vast basin of the Wealden had been forced up and broken at various parts of its area, after the deposition within it of deep-sea drift, and the accumulations of the cretaceous strata, but that this basin itself had been formed by a gradual depression of the earth's crust, after the distinct existence of dry ground covered with trees, as exhibited by the Portland dirt-bed. It is difficult to reconcile in the mind such oscillations with the comparative quiet which now reigns on the earth; but we become acquainted with them from geological investigations, as we do with the facts, the habits, and opinions of past ages, from historic records; and we owe therefore to this science the knowledge we now possess of changes which, without it, would have been unknown to us. In England, where the formation is more extensively developed than in any other country, the base of it is the well-known Purbeck limestone, distinguished by the profusion of fresh-water shells it contains. This portion of the formation, the beds of limestone being separated by marls, is about 250 feet, which must be considered an immense depth for a fresh-water deposit. The Hastings sands with clays and calcareous grits succeed, and are about 400 feet thick, being as extraordinary as a fresh-water drift, as the Purbeck limestone is as a calcareous deposit; and the whole is covered by the Weald clay, which, with its thin beds of sand and shelly limestone, is about 200 feet thick. This formation, taken together, implies the existence for a long time of vast areas of fresh-water resembling those of North America, in which at this moment, from the continued wear of their banks and the depth of their bottom, in some cases below the level of the sea, there can be no doubt extensive deposits are forming. The recent discovery by Mr. Beckles of numerous mammalian remains in the Purbeck beds has given a new interest to this formation. These fossils have been examined by Dr. Falconer, and will be speedily published; one new genus has been formed, and it is probable that others may yet be discovered.

Though not marked out in the same striking manner as in England, this formation of fresh-water deposits can be traced in other countries; and it is evident therefore that a very large portion of that part of the surface of the earth now constituting Europe was covered with fresh water. In Westphalia, the Wealden is represented by a deposit 800 feet thick, consisting of sandstone and bituminous marl, with layers of coal and of ironstone and beds of limestone, the whole being characterized by fresh-water fossils. In Saxony, at Niederschöne, the formation is reduced to a deposit 40 feet thick, of dark-coloured sandy shale and marl, which is sometimes bituminous, and contains traces of coal, with an abundance of vegetable remains. Amongst these fossil plants only one shell has hitherto been discovered, but that is a most characteristic one, belonging to the fresh-water genus anodonta, which often prevails exclusively in muddy lakes and pools. The quadersandstein, or green-sand, overlies this deposit, and Cotta thinks it probable that the beds of this formation in Silesia, which contain coal and the remains of plants, should also be allotted to the Wealden. Amongst the numerous reptiles of this epoch appear tortoises of genera which now occur in fresh water in tropical regions. The iguanodon, so called by its discoverer, Dr. Mantell, from its analogy with the living iguana, was an herbivorous reptile, and appears to have abounded at this epoch. The nature of the fossil plants, and the number and magnitude of the reptiles, show that the climate still continued tropical. Practically, the Purbeck limestone is well known as lumachella marble; the desig-

nation lumachella being derived from the Italian word *lumaca*, a snail, and applied to those varieties of limestone which, with a granular or marble structure, abound in fossils. Caution is required in selecting this stone, as much of it easily disintegrates, and in all specifications for its supply a sample should be referred to, in order to ensure the delivery of the proper kind; a remark which may be extended in various degrees to almost every building stone. The sandstones are friable, and by their wear produce very picturesque scenery, as about Tunbridge; the clays form a strong soil, as in the rich district of the Weald of Kent.

CRETACEOUS.

Succeeding to the extensive fresh-water formation which has passed under review, comes a still more extensive and generally more widely diffused marine formation—the cretaceous. To bring this change more clearly to the mind, it may be well to imagine what would be the result, if, after ages of tranquil deposit of fresh-water detritus in the depths of the lakes of North America, their surface was depressed, as their bottom now is, below the sea level. Such a depression would cause, even if carried to a very moderate extent, an irruption of the sea over a large portion of the country, and marine deposits would immediately commence. If, again, after the accumulation of deposits equivalent in thickness to the cretaceous, the whole mass were uplifted by the action of subterranean forces, the fresh-water deposits might be brought to view by the fracture and removal of part of the marine covering, whilst the remaining part of that covering might continue as a mural boundary surrounding them. In such a case, a result analogous to that of the Wealden and chalk would be produced. Commencing at its base, the cretaceous system is sandy, and this division has been named the green-sand formation in England, the quadersandstein formation in Germany,—the names pointing to the principal peculiarity of the sandstone in each locality.* In each it admits of further subdivision into upper and lower, the two being separated in England by a deposit of marl and clay, called gault; in Germany by one of marl, marly sandstone, and limestone (the plänerkalk). But though there is in these divisions a striking conformity when viewed at particular localities (if, for example, the green-sand of England be compared with the quadersandstein of Saxony and Bohemia), considerable modifications appear in other localities. In Westphalia and North Germany, a conglomerate and a clay which Cotta considers the equivalent of the Specton clay occur below the lower quader; the pläner is replaced by a blue clay with crystals of gypsum, corresponding even nearer with the English gault; the upper quader is represented by a green-sand, which is surmounted by bright red marl. The sandstone of the Carpathian Mountains is also, as has been before noticed, referred to this epoch. On the Continent, there are likewise modifications as to the upper limit of the green-sand, the same lithological character, in sandy marls and sandstones, extending, in Westphalia and North Germany, high up into the upper section of the cretaceous system; but such variations are natural, being the necessary result of those local peculiarities which have already been so frequently adverted to. In England, the upper section of the cretaceous formation admits of a subdivision into the lower chalk without flints, and the upper chalk with flints, the whole reposing on the chalk marl,—a subdivision which is purely local. In Saxony and Bohemia, the whole section is reduced to beds of flints; in Westphalia and North Germany, the upper member, or the white chalk, is feebly represented, but all below it consists of chalk marls and sandstones, far more resembling the green-sand, though by their fossils proved to be the equivalent of the chalk. In France, the Maestricht beds are at the summit, resting on the white chalk with flints, and from their peculiarities have been considered by some geologists to be-

long to an upper member, approximating the chalk to the tertiary strata, though the fossils are those of the white chalk, whilst the chalky character is carried downwards into the green-sand. All these modifications of lithological character must be anticipated by the geologist, and his skill is exercised in seeing through the obscurity to which they give rise, and tracing out the boundaries of sea and land, of bay and ocean, at each successive epoch. In doing this, he will sometimes find that the mineral conditions remain unaltered from one geological epoch to another, as is certainly the case in the Mediterranean, the scaglia, or white limestone, with its flints, having been in part deposited during the oolitic and in part during the cretaceous periods.

Few phenomena are more striking, or have engaged more attention, and excited more speculation, than the occurrence of long lines of flints in chalk. The marked contrast between the dark hue of the flint and the pure white of the English chalk, has without doubt led in the first instance to the special attention given to chalk flints, as the occurrence of siliceous nodules similarly arranged is not confined to the chalk, having been noticed in the mountain limestone and in the oolite; nor is the arrangement by nodules always the prevailing one, as, in the chalk of Ireland, for instance, extensive layers or beds are very common, as they are also in the oolitic and cretaceous portions of the white limestone of the Mediterranean.

The origin of chalk flints has excited much speculation, though it is evident from the preceding observations that the question cannot be confined to the chalk alone. A microscopic examination of the chalk flints has shown that they contain numerous infusorial remains, and in consequence Ehrenberg was disposed to consider that they had been formed almost exclusively of such animals. On the other hand, the discovery of the texture of sponge in the flints has led others, at the head of whom is Mr. Bowerbank, to ascribe them in like manner exclusively to a spongeous origin; and a third party is more disposed to look upon the silica as having been held in solution by thermal waters, and, either in solution or when depositing in a gelatinous state, to have enveloped the sponges and other bodies it contains. It is highly probable that all these actions have contributed to produce the result observed; and when the observations which have been made on the peculiar affinity of silica for organic substances are considered, there can be little doubt that sponges have materially contributed to the production of chalk flints, though without being considered a necessary basis for all flints. As yet, the comparison of flints and cherts in various formations has not been carried out in a perfect manner, but it may be assumed as certain that they will be found to exhibit a material and characteristic difference in their zoological remains. Even to the practised eye the difference between the fragments of flints of various formations is scarcely perceptible, but they are commonly confounded together, as is the case with those spread out on the shore of our southern coast, which are all called *chalk flints*.

In fossils the cretaceous system is peculiarly rich, the whole mass of the white chalk swarming with infusoria and other microscopic animals, in addition to the multitude of those of larger dimensions, as echinida, cephalopoda, etc. The spongiadæ and alcyonidæ are abundant: of the crinoidæ there is the peculiar genus marsupites; of the echinida, the genus ananchytes, and a profusion of species of many other genera; of the mollusca generally the remarkable genus hippurites, the true nature of which is yet doubtful, deserves special attention: the genus spondylus (plagiostoma and podopsis) has a very characteristic species in plagiostoma spinosum; the genus pecten affords in P. quadricostatus and P. quinquecostatus the type of a new genus; the genus inoceramus abounds; whilst of the cephalopodous division there are many most characteristic genera and species, such for example as the genus turrilites, a chambered

shell with an external turreted form, the beautiful genus baculites, which unites a straight form with the sinuous septa of the ammonites, the hook-shaped hamites, and a great number of ammonites and nautili, producing in this order alone an assemblage so strangely different from that of our present tropical seas, where a single nautilus alone remains, as justly to excite our admiration and surprise. In fish there is a nearer approach to the existing epoch, as the genera squalus, galeus, and lamna occur; of reptiles, there is the peculiar genus mososaurus. This is only a faint outline of a formation so interesting in England, though it may be considered a sufficient guide for the Engineer in other countries. Practically, the chalk hills are well known for their smooth outline and surface, and for the short herbage of their downs, so fitted for sheep pasture, whilst the marly beds of the lower portion of the system have long been known for their fertility, as specially noted by White of Selborne. In countries where the chalk is of a more indurated character, resembling the oolites, as in Greece, the tame character of its hills is changed to a far more bold and striking outline, resembling that of mountains of quartz rock. The value of the chalk for its lime, being easily worked and burnt, is well known, and though soft, it can be used as a building stone. The white limestone of the Mediterranean is in part cretaceous, and is an excellent building stone, though, being very brittle, it is dangerous in such portions of military buildings as are exposed to cannonade. The flints, made up into a species of concrete and strengthened by stone quoins, were extensively used in the walls of ancient churches, and are still so applied; they are also used as a road stone, but, as they break into angular fragments, with sharp cutting edges, they cannot be considered well fitted for such a purpose. In the lower part of the system, as exhibited on the Continent, the green-sand or quadersandstein becomes more practically useful than it is in England, though the soil proceeding from it is, on the other hand, much less fertile. In Saxony, the quadersandstein,—so called from its breaking into quadrangular portions,—is celebrated as a building stone, the colour being pure and good; and it is remarkable that the pläner (or gault) is there almost deficient, so that the upper and lower quaders are nearly in contact, and each yields its valuable bed of building stone. In other localities, as at the foot of the Schneeberges and in the Gottleube Valley, the existence of the pläner is known from a line of water-springs which it throws up; and this fact is noticed here as illustrative of the theory of springs, which will be again referred to at more length. Westward the pläner, which had almost thinned away, takes an unusual development, stretching up into and occupying the place of the upper quader, which is there wanting. Such variations as these are most instructive to the experimental geologist in his practical applications, and the character of the deposits is also well displayed in the German districts which have been described. In the valley of the Elbe, the boundary hills are of granite and syenite, as the bottom of the valley itself is at Meissen; and yet in boring at Dresden, a depth of 856 feet was passed through without arriving at the granite. If now we could imagine this accumulation of quadersandstein and plänerkalk to be removed, and the basin containing it laid bare and then filled with water, an inland sea would be formed, the bottom of which would be more that 500 feet below the present sea level, and the surface of its waters about 300 feet above; but the sandstones and limestone were evidently a marine deposit, so that after an epoch when in countries not very distant from it land plants were growing and an extensive fresh-water deposit forming, this basin must have been depressed more than 300 feet below its present level, and though now it would be a lake, if filled with water instead of mineral matter, it was then a deep hollow in the sea. Here, then, is another of those surprising results, similar to that pointed out in the Wealden, which geological research has made known.

TERTIARY CLASS OF FORMATIONS.

At this period of geological history, glimpses are obtained of the present order of creation, animal species which still exist appearing amongst the relics of the past. This circumstance throws over the tertiary strata a high degree of interest, and it has been made by Mr. Lyell the groundwork of his subdivision of them, the terms adopted signifying, as it were, the dawning and gradual progression of the existing light, and the basis of subdivision being laid on the proportional number of existing species as shown in the following Table.

Periods.	Localities, etc.	Percentage of recent species.	Number of fossils compared.
Post-Pliocene ...	Fresh-water of Valley of the Thames	99 to 100	40
Newer Pliocene	Marine strata near Glasgow.....	85 to 90	160
Older Pliocene {	Norwich crag	85	81
	Suffolk, red and coralline crag.....	54	436
Eocene	London and Hampshire	1 or 2	400

The consideration of this Table naturally gives rise to this remark, that the two lower subdivisions are more soundly established than the upper, as the comparison is made upon large and nearly equal numbers, so that the discovery of a very considerable number of recent species would be necessary to affect materially the comparison; whereas in the upper, the numbers are so much smaller, and so unequal, that the results might be materially disturbed by the discovery of only a moderate number of recent species. It is necessary also to bear in mind, that in approaching the existing epoch, and the organic constituents of the present creation, it is only natural to expect that evidences of similar physical conditions should be discovered; and as the fauna and flora of various parts of the present world are widely different from each other, so also must have been those of different localities, in periods which exhibit so much of the zoological characters of the present. In determining, therefore, the exact place of a deposit in the series of tertiary formations, the comparison of fossils should be made with the recent species of the neighbouring coasts and seas, the fauna and flora of each local deposit becoming, as it were, independent, just as the fauna and flora of many recent localities are. On this principle, so well explained by Mr. Lyell, the contemporaneous fossils in deposits of each tertiary epoch, and specially in the more recent, may, at various parts of the earth's surface, have scarcely any resemblance to each other, although in each locality conforming to the general rule of a growing approach to the recent types. The tertiary formations must therefore be considered as made up of many local formations, the exact mutual relation of which to each other it is sometimes very difficult to determine. The marine and fresh-water beds appear to have been deposited in extensive basins, and it is remarkable that the great cities of London, Paris, Mentz, and Vienna have been founded on such ancient basins. The great brown coal formation, however, which is spread over a large portion of Germany, and abounds in land plants, does not appear connected with a basin sufficiently marked by any depression of its surface to explain so deep an accumulation of vegetable matter as may be seen, for example, at Zittau in Saxony. In general, the tertiary deposits of England do not attain any great terrestrial height, no very material elevating force having been exerted beyond what was necessary to raise them partially above the sea level; but along the axis of greatest movement, both in Europe and America, the case is different, the Nagelflue of Switzerland, with its

brown coal and limestone, skirting the Alps in a chain of mountains 6000 feet high, the thickness of the deposits being 2000 feet. Such deposits are very widely spread, occurring in North and South France, in the South of England, as also, in its upper members, in Scotland and Ireland, in North Germany, and along the Rhine in Middle and South Germany, on both slopes of the Alps and Apennines, in Sicily, on the coast of Africa, and specially on the shores of the Mediterranean, in Poland, in North and South Russia, in North and South Asia, as for example in the Bay of Bengal, in the East of North America, and in Equatorial America, etc.; so that in almost every part of the globe traces have been found of that gradual approximation to the present physical and zoological conditions of the earth's surface, which is learned from the study of tertiary deposits. The general evidence of the fossils, especially in southern regions, leans towards the existence of a tropical climate within this epoch, the divergence from such a climate being as yet small in such positions, except where, as in Switzerland and South America, it has been augmented by elevation of the surface from internal disturbance.

In a few Northern localities however there is a tendency in the evidence towards a colder climate within the later tertiary epoch; nor is this unnatural, as in that portion of the earth which approaches towards a region of low mean temperature, a very slight modification of the terrestrial surface might have been sufficient both to depress the mean, and to check those variations to a higher summer temperature which must materially affect the growth of all animals possessing the power of even partial locomotion.

EOCENE.

The English tertiary deposits are important in the lower and upper members only, the middle being nearly wanting. The basins of London and Hampshire are the lowest geologically, and belong to the eocene period. They are bounded and underlaid by the chalk, and their strata consist of sands, clays, and gravels. On the variation of mineral character, a subdivision into the upper sand or Bagshot sand, the London clay, and the plastic clay, was at first proposed, consisting of alternating beds of clay, sand, and shingle; and though such peculiarities of deposit can only be considered useful as indications of the physical conditions of a deposit which may vary in different localities, the eocene has now been satisfactorily divided into lower, middle, and upper eocene. In the shells there are several nautili and others of a tropical type, and many also in the plants, more than seven hundred of which are supposed to have been discriminated; and again in the reptiles, the teeth and bones of many crocodiles and turtles, and even the bones of a large serpent, have been found. The remains of a bird, of various quadrupeds, and of a monkey of the genus macacus, all correspond in this testimony to a warm climate. The deposits of the Paris basin are singularly different from those of the London basin, being composed of a coarse white limestone, calcaire grossier, a siliceous limestone with beds of crystalline gypsum and of flint and marls, with some clay and lignite. The chalk basin, which is thus filled up, is very extensive, being 180 miles long and 90 miles wide, and when first described accurately by Cuvier and Brongniart, was supposed to embrace the whole series of tertiary deposits, and to be subdivided into several distinct formations; but more recent examination has led to a different conclusion, and the several variations from marine to fresh water are more reasonably accounted for on the principle of the discharge of fresh water, with its deposits, into an extensive gulf. This modification has brought the English and French Formations into geological connection with each other, and, as might have been expected, fresh-water deposits are also found within the English gulf, as at Headon Hill and Binstead in the Isle of Wight,

many of the quadrupeds of which locality correspond with those of the celebrated Montmartre gypsum quarries which were the classic ground of the great Cuvier's wonderful researches and discoveries. Practically, the great mineral difference in these deposits in the two basins must give rise to similar differences of application. The clay beds of the London sometimes abound in nodules of a calcareous stone, used for making Roman cement. These nodules often contain marine shells, and sometimes the remains of turtles and fruits. When traversed by cracks and veins dividing the mass into parts, as by septa, they are called septaria. Harwich and the Isle of Sheppey are well-known localities of the nodules. In the Paris basin, the calcaire grossier furnishes, in some of its varieties, very good building stone, and the siliceous fresh-water deposit yields an excellent millstone. A careful microscopical examination of the flints of the Paris basin and of those forming the shingle of the London basin, as compared with the true chalk flints, is yet a desideratum, and may throw considerable light upon the direction of the drift during this period. Mr. Prestwich has made an important alteration on the first views upon this subject, by proving the true London clay, including the Bognor clay, to be more ancient than the calcaire grossier, and therefore to correspond with the sands, etc., of the Paris basin; he discovers however, in part of the Hampshire series, the true equivalent of the calcaire grossier, which becomes therefore a member of the middle eocene, the London clay and underlying beds forming the lower eocene. The range of the London clay has been extended through a large portion of the N.E. of Europe by Dr. Girard, of Berlin.

MIOCENE.

The shelly sand and marls of the celebrated faluns of Touraine have been allocated to this section of the tertiary deposits. The deposits of Piedmont, Lisbon, Styria, and Mayence, though connected by characteristic fossils with this epoch, exhibit each its peculiar modification of mineral character; but the molasse of Switzerland, from which the Germans call the whole tertiary class "molassen," specially deserves notice. It is a vast mass of a soft sandstone, which probably belongs in part to several portions of the series, and it derives its name from the ease with which it is cut in the quarry. The fossils are local, but have hitherto tended to place at least a large portion of the deposit in this section.

Practically, the formation varies in importance in different districts. In Suffolk, the coralline crag yields a soft building stone, and the marls are useful as manure. In the Styrian Alps, limestones of a coralline and of an oolitic structure are largely developed, and the molasse, from the ease with which it is cut, is also valuable.

PLIOCENE FORMATIONS.

It is unnecessary to dwell long on the upper or newer pliocene formations, as they are very feebly represented in the British Islands, being confined to minor deposits of sand, gravel, and clay. On the Continent however (and this is quite consistent with the theory of the gradual progression southward of geological formations) they become very largely developed, in Sicily extending over nearly half the island, and attaining an elevation of 3000 feet, being composed partly of calcareous and partly of argillaceous strata, and exhibiting by the occurrence of recent species of shells amidst such a mass of stratified matter, a striking proof of the accuracy of geological reasoning as regards the older formations. The older pliocene in England is now considered to embrace the Norwich crag, as also the coralline and red crag of Suffolk. In Italy, the Sub-Apennines are again a striking exemplification of the great development of these comparatively recent strata; and the blue clay of the Mediterranean, rising sometimes to the height of 1000 feet above the sea, is also of this

epoch, and the lacustrine deposit of the Val d'Arno, so rich in the remains of mammals, is also a member of the pliocene formation. In Sicily, the newer pliocene, though so vast, is still marine in character, but in Russia the singular phenomenon is again observable of an equal extension of fresh-water deposits, a vast mass of argillaceous limestone occurring around the Caspian, which Sir R. Murchison calls the Aralo-Caspian, or Steppe limestone. The univalve shells of this deposit are of fresh-water origin, and are associated with bivalves, which are common to partially saline or brackish water, but there are no corals, so that the true characters of a deposit in an inland sea are fully exhibited. The thickness of this supposed member of the pliocene is in some places between 200 and 300 feet, and it attains elevations of 700 feet above the present level of the Caspian. It is remarkable that whilst the species of testacea of the newer pliocene formation were nearly identical with those of the existing period, there should still have been so marked a distinction in the animals of a higher class, as is seen in the bones of the various celebrated bone caves and ossiferous breccias of all parts of the globe, a difference which extends even beyond the limits of the pliocene. There is also this remarkable fact, that whilst in the old world the general type of such elevated organisms is in conformity with that still existing, though indicating the extension of the animals now confined to warm climates far northward of their present limits, there is in that singular country, Australia, a type peculiar to itself, and extending back to this period; so that it may be assumed that in the tertiary epoch this vast region was already isolated from the rest of the world: and is it not almost allowable to imagine, when the degraded character or type of its population is considered, that man is even there a relic of pre-existing creations?

In India, much has been done by our brother Officers of the Indian Army, Major Cautley and Dr. Falconer, to elucidate the natural history of this epoch by collecting and describing the bones of extinct animals; and Captain Vickary has very recently shown, that in the Beloochistan Hills a large assemblage of beds of sandstone, of conglomerate, of clays, and of bone gravel, belong to the tertiary formation, the base on which they rest being a nummulite limestone; and when the difficulties attendant upon an Eastern climate are considered, such exertions may well be a stimulus to those who are serving in climates more favorable to physical exertion: the Indian Geological Survey is now in full progress under the superintendence of Thomas Oldham, Esq.

The connection of the ancient lava currents of Auvergne with the tertiary strata has already been noticed, but it requires a few additional remarks. The age of the stratified deposits of the country is considered by Mr. Lyell to be generally eocene, although some portions may possibly extend upwards to the miocene. The base of this system is granite, and therefore either eruptive or metamorphic of a more ancient date. If then the deposition of these strata had ceased, and the surface been upheaved prior to the later members of the tertiary period, the evidence of a former though still continuing wear might yet be found, as the general effects of river action combined with lava currents afford in this singular country many proofs of the lapse of a vast extent of time, during which the physical features of the district had been only modified by sub-aerial agencies. In Plate IV. fig. 24, Lyell's figure of successive gravel beds which represent alluvions of different ages, covered by lavas, exhibits these phenomena; and his still later inquiries have shown that in the Valley of the Couze at Nechers, the lava current of the Puy de Tartaret has passed over a red sandy clay rich in the bones of mammalia, which are associated with some of reptilia and of birds, and with several *recent* land shells. The bones, though closely allied to those of recent species, are considered distinct, and include the equus fos-

silis of Owen. Mr. Lyell, from the superposition of the lava, is enabled to affirm that the bone beds, in whatever way the animals were destroyed and their relics so imbedded, belonged to the alluvial formations of the river bed and river plain at the time of the flowing of the lava of Tartaret; whilst he shows, from the existence of an ancient Roman bridge, not more recent though probably much older than the fifth century, which spans with two arches the River Couze, abutting on both banks against the lava, which had thus been cut through and formed into the present existing ravine fourteen centuries ago, that, as respects the events of human history, the lava of the Puy de Tartaret was at least of great antiquity. On the whole, Mr. Lyell considers this lava to be a type of the products of the most modern volcanic eruptions of Auvergne, and to be referable either to the close of the newer pliocene or to the post-pliocene period, a period when, as before noticed, "the mollusca were identical with those now living, although a great many of the mammalia belonged to species now extinct." This recurrence of alluvions, and even of ossiferous beds, with overlying streams of lava, deserves the attention of the few who, from reasons not geological, would still consider the stratified deposits of the earth as the work of one great flood, as it is utterly impossible to reconcile such volcanic eruptions to so limited a theory. In a practical point of view, it has already been shown that in countries where the tertiary strata are fully developed as either deep sea or great lacustrine deposits, they supply valuable building materials both in limestone and in sandstone; and it may be also stated, that the celebrated Carrara marble, once considered primitive, belongs to the tertiary epoch. The fossil bitumen, so extensively used in asphalte pavements, namely, that of Bastenue, a small village of the South of France, 15 miles north of Orthez, is tertiary. The formation in which the bitumen is found rests on a sandy limestone, which has been allocated to the cretaceous system. The overlying beds are variously coloured sands and clays, which are 50 or 60 feet deep, and covered by gravel and sand, which extend many miles in every direction. The beds are usually horizontal, though sometimes much disturbed by the intrusion of igneous rocks. Under about 45 feet of the variegated sands and clays, the bitumen appears in small quantity in a bed of blackish sand, 4 feet thick. From 5 to 15 feet of bitumen are then observed, the upper part mixed with loose and coarse sand, the lower being more compact, and mixed with finer sand. In some places, from 10 to 15 feet of sand, without bitumen, occurs, whilst in others the bituminous sand is thicker, and rests directly on the secondary sandy limestone. In two localities, marine shells have been found in the bituminous sand, and Mr. Pratt refers them to the miocene period. The shells are arranged in layers, and are quite perfect, the valves not being separated from each other; and the bitumen, when in a soft or liquid state, was, in Mr. Pratt's opinion, forced into the shells, after their deposition in the sands in which the animals lived, as even the smallest cavities are filled. The eruption of the bitumen is supposed to have been connected with the appearance of the ophite, an igneous rock which has produced such great changes in the Pyrenees. The bitumen is easily cut when first exposed, but in a few days it hardens so much as to become incapable of purification: the purification is effected by boiling the sandy mixture in a large quantity of water two or three times, when, by continued and careful stirring, the sand gradually settles to the bottom, while the pure bitumen rises to the surface and is taken off. A small portion of bitumen occurs in the tertiary rocks of Anti-Paxo, and again in a larger quantity at Zante. An inspissated tar or pitch of probably a juniper is used for similar purposes in the Morea, and has been tried with tolerable though varying success at Corfu. A large quantity of coarse sand is mixed with the tar when heated, so that it forms a bituminous concrete. The variableness of the result, from the different qualities of the crude ma-

terial and the difficulty of manipulation, is against the use of this material; but it is probable that were the process of nature imitated, and the crude tar subjected to long boiling, and after being forced into a mass of heated sand, treated as the fossil bitumen is, it would be found nearly equal in quality.

The existence of gypsum and salt in the tertiary stata has been already noticed.

QUATERNARY OR POST-PLIOCENE.

Our inquiry has now come to that point where, on one hand, we still see in the recent results of geological phenomena evidence of the formative processes of nature, —coral reefs still rising from the depths of the Pacific,—conglomerates being still formed in the Mediterranean,—beds of marl being still deposited in lakes,—travertin being deposited from mineral springs,—and peat being observed to have formed over fresh-water shells, the bones of land animals, and even the works of human art (in one instance, in the county of Galway, an ancient hut with a paved passage having been laid bare by the removal of peat 30 feet deep); and on the other hand, we are still kept at a distance from the recent epoch; for although the shells found are all of recent species, they are generally arranged in positions and associated with detritic matter of such a description, that their appearance indicates the action of forces prior to the present order of things. These masses, the true post-pliocene, though now exposed to view and frequently found at high elevations and of great depth, have evidently been, like the antecedent formations, under the level of the waters of either lakes or seas, whilst the recent strata must necessarily, in most cases, be yet in the position from which the former have emerged. The beds of sand and gravel spread over so large a portion of the earth have always attracted attention, and for a long time were considered so many results of the passage of the diluvial waters over its surface; but a rigid examination of the peculiar characters of these deposits has shown that such an opinion is untenable: for example, they are sometimes found to consist of deep beds of sand, separated by fine clay partings into a multitude of beds; sometimes they are composed of alternating layers of sand and gravel, some of which, as shown in Plate III. fig. 14, exhibit cross lamination; sometimes they consist of clay with imbedded boulders of various rocks and of various sizes, the term boulder being properly applied to rolled or round masses; sometimes they contain marine shells, sometimes bones, and sometimes they extend over large spaces and occur at great altitudes and of great thickness, without any trace of organic bodies. Many marls and clays or silt, with land and fresh-water shells, belong to this division. When the various circumstances attending such deposits were considered, it became evident that they could not be brought within the sphere of action of any one great wave, or even within the action of tumultuous waters continued only through a very limited time, and it became necessary to seek an explanation by classing them with the ordinary phenomena of nature. That the substances forming these deposits have been broken up, triturated, and moved by water, cannot be doubted, and the term drift therefore has been applied to many of them; but of course, though all such matter and substances have been more or less drifted, the distribution of them must have been modified by many local peculiarities, giving rise to deep deposits of sand in one place, and to long continuous banks or shoals in others. That such modifications of recent drift are now taking place, the sounding lead sufficiently declares; and it is easy therefore to apply the same reasoning to ancient drift. One great progressive step has been only recently taken, by separating the great "erratics," or those large angular masses of rock which are often found resting on the surface of sand or gravel, from the beds on which they rest, and thus distinguishing them from the rounded boulders, which are sometimes con-

nected with the latter, and at others heaped up with clay as deep accumulations in hollows.

It would be impossible to detail here all the peculiarities of such deposits, sometimes assuming, as shown in Plate III. fig. 14, great regularity, the boulders being generally at the top, and at others exhibiting a confused mass; but the reasoning on which the theory of the distribution of such sand, gravel, boulders, and of "erratics" rests will be readily understood from an abstract of Sir R. Murchison's 'Papers on the Detritus of Sweden.' That able observer having, in his work on Russia, discussed the well-known phenomenon of the long lines of detritus, dotted here and there by "erratics, or angular fragments," which stretch from the Northern regions into Poland and Germany, proceeds to examine the circumstances of the detritus in Sweden, including Gothland and Dalecarlia. In Scania, the most southern province of Sweden, or that most distant from the great source of the erratics, the fundamental rocks are chiefly cretaceous, and they, together with two detached hillocks of the oolitic period, are covered with detritus of sand, mud, and *rolled* northern boulders, angular superficial blocks being rare: but here, amidst these worn and travelled fragments, occur, and in Sweden only here, the remains of great land quadrupeds; so that Sir R. Murchison infers, that though the more northern portions of Sweden may have yet continued under water, this portion, like the continent to the south, must have been raised above the waters, and inhabited by such animals either just before or contemporaneous with the existence of man; this latter inference being principally founded on the researches of Professor Nilsson, who extracted a perfect skeleton of the Bos Urus, or B. primigenius, from beneath ten feet of peat, the horns of the animal having been deeply buried in the subjacent blue clay, and on close examination discovered in the vertebral column a perforation which corresponds exactly to the form of wound which would have been inflicted by one of the stone-headed javelins of the aborigines of Scania. Professor Nilsson strengthens this deduction by the existence, of which he considers he has proof, of bogs containing these land animals, and even affording evidence of the co-existence of man, which have since been submerged and covered by gravel and sand; and Sir R. Murchison considers the bogs of Scania as a parallel case with those of Ireland, under which the remains of the great fossil elk, Megaceros Hibernicus, are buried; although the two cases can scarcely be parallel if it be admitted that the bogs of Scania have actually been covered by marine drift. Leaving aside this obscure point, and proceeding north and east into a more elevated district, the materials of the northern drift are observed to be arranged in linear directions, forming great traînées, which, however, are not so strikingly developed as in the "Osar," or longitudinal zones of gravel of Central and Northern Sweden. Traversing the country towards Christianstad on the east, a ridge of gneiss on which some "erratics" rest, a tract of sand, ten miles wide, without a single large block, is met with,—then at intervals traînées of gravel with blocks, and on nearing Christianstad, sandy hills are observed, which rise 300 feet above the plain, and have on their summits clusters of angular blocks, whilst such erratics are rare in the plain itself below them (see Plate VII. fig. 35). In some of these hills, where subsidences have occurred, vertical thicknesses of sand layers are seen, 40 to 50 feet thick, beneath the great blocks, all of which are more or less angular, and some of them 8 feet to 10 feet in diameter. Sir R. Murchison here observes, that these sandy accumulations, from their form and siliceous texture, have all the appearance of having been fashioned by currents of water, whilst they are surmounted by isolated groups of angular blocks which, from their composition, must have been derived from the countries on the north (the substrata to the south being entirely different), and transported across the wide low tracts which lie around Christianstad.

Proceeding further northward, and finally into Northern Sweden, the phenomenon of long traînées is still more strikingly exhibited, whilst the rocks are worn down in undulating surfaces, and examples are exhibited of rounded northern and abrupt southern sides. It is unnecessary to pursue these details further, and it may be therefore generally remarked, that the superficial detritus, so long called diluvium, exhibits itself in several distinctive phases. 1. That of deep beds of sand, not heaped up in one mass, but manifestly deposited in successive layers, and therefore, though doubtless triturated by the action of water, and even moved along by currents, to be considered as comparatively tranquil and regular deposits. 2. Lines of gravel and of gravelly clay with rounded boulders, which sometimes surmount the more quiet deposits, and by their definite direction in such traînées for even hundreds of miles, indicate the action of powerful currents, moving in Northern Europe, in a slightly divergent direction, from the Scandinavian Mountains to the south on one hand, and from the south to the north on the other; this latter remarkable fact being the result of Sir R. Murchison's recent inquiries, and seeming to indicate that the transport was not effected simply by the usual submarine currents flowing from north to south, but partly, at least, by undulations of the bottom, which caused powerful waves of translation in all directions from the axis of disturbance. 3. "Erratics," or large angular blocks, which are found not immersed in the sand, mud, or gravel, but resting on its surface, or on ridges of rock, where there is no such superficial covering; and that it has been impossible hitherto to adduce any sufficiently satisfactory cause of the translation of such masses, which, having preserved their angles, cannot have been exposed to the rolling action of water, other than that of moving ice. 4. In the preceding cases, the detritus is supposed to have been foreign, or to have travelled; but it is very often in part local, and then indicates the wear of the adjacent rocks, both by the direct action of the sea against them, and by its power of attrition in moving fragments along a coast or a bank. Where both forms of detritus occur, great care should be exercised in discriminating between them, and determining which of the two is the underlying or overlying. 5. Connected with this question is the phenomenon of what have been called raised beaches, although it must not be supposed that each of these has actually been a beach, in the ordinary sense of that term. Mr. Smith, of Jordan Hill, in tracing the successive upheavals which have given to the rock of Gibraltar its present form, notices several modern detritic beds which contain recent marine shells and occur at various heights up to 700 feet above the present sea level. Some of these beds are connected with ancient sea-worn caves, and would be therefore justly classed with the effects of a sea beating against a beach and cliff: but if the phenomenon be observed more extensively, it will appear at least possible that some such deposits are merely forms of current drift, and were not, strictly speaking, beaches.

Sir R. Murchison, in the statement of his hypothetical views respecting the condition of Gothland, from the period of the consolidation of the Silurian limestone which forms its basis, may be quoted as illustrating this subject. He there supposes the ancient limestone to have been eroded, whilst yet beneath the sea, by ordinary marine action; but it has been justly observed, that this description of action is as yet little more than conjectural. He then supposes this limestone exposed to powerful denudation, by the passage over it of heaps of fragments of crystalline rocks drifted from the north, and impelled forward by powerful waves of translation, according to the theory of Mr. Scott Russell and Mr. Hopkins, by the wearing action of which the exposed northern face and the summit were, it is supposed, broken, polished, grooved, and striated, whilst the drifted rollers were shot over the southern escarpment, and lodged at its foot, there forming a bank of gravel, without wearing away the lee or

protected side of the still submarine hillock. The waves of translation having subsided, a glacial or ice-floating epoch supervened, during which icebergs and ice-floes transported large angular blocks, and deposited them sometimes on the surface of the denuded limestone, and sometimes on the water-worn gravel or Osar, and at length, the island having been uplifted above the level of the sea, it would exhibit traces of these past actions in its worn northern face, in its summit cap of gravel surmounted by angular "erratics," and in the gravel bank at its southern base, which would *then become* a beach. New elevations would raise the island still higher, and now, by the action of the waves against its surface, *local* gravel would be formed of the fragments of the limestone, and real beaches be fashioned out of it.

It is unnecessary to pursue these speculative details further. Similar phenomena have been observed in America, and whilst in Europe the boulder formation has been traced southward to the 52° of latitude, in America it has been observed to extend to 38½°; to be occasionally more than 200 feet thick; and to bear on its surface vast "erratics," one, a block of greenstone 100 feet in circumference, having been noticed by Mr. Lyell on the summit of a high hill of sandstone;—the large European erratic on the Island of Fohnen measuring 44 feet across,—whilst the surface of rocks, when laid bare, are observed, as in Europe, to be striated, furrowed, or smoothed. The universality of these phenomena in a space extending from the northern elevated districts towards the south, points to some general force, such as that which now effects the transmission of the Polar waters to the Equator, and although such an action may be aided by the waves of pulsation consequent on the elevating forces, it seems difficult to account for the effects by these latter forces alone. Further, as the "erratics" pursue a similar direction with the long traînées of gravel, they show that the currents preserved their general direction for a long period of time, and that such direction was in conformity with that which the present course of icebergs exhibits. Sir R. Murchison however points out, that to the north of the Scandinavian chain, the "erratics" have moved to the northward; but their extension in that direction has not been traced sufficiently far to remove them from the possible action of glaciers. Finally, in considering or discussing these, or indeed any geological phenomena, it must be remembered, that though one particular set of causes may be demonstrated to have been in action by the evidence of one class of facts, such proof does not exclude the co-existence and co-operation of other causes, and that the only way of obtaining a satisfactory solution of the phenomena is the consideration of all such causes. It is thus, that whilst the discovery of marine shells under or in the transported gravel in so many localities, indicates that a large portion of the earth's surface over which it has been distributed was then under the sea, it does not preclude the possibility of currents in large lakes, such as those of North America, produced by the out-draughts of large rivers, and carrying with them masses of ice, loaded with gravel, and perhaps surmounted by erratics: that whilst it seems impossible to account for the transport of such huge masses of rock, and for the angular condition of erratics by any other transporting force than that of ice, it would be unphilosophical to exclude either form of that force, the one being only a necessary result of the other, as the glacier must have co-existed with the floating sheet and berg of ice. The great extension of "Escars" and "Osars" indicates the action of currents through a very great space; but the elevatory forces may have produced waves of translation during the same epoch, and given rise to the formation of radiating lines of gravel, and by the modification of the usual action of currents, have at the same time led to the deposition of "erratics" upon them; and, whilst currents and their accompanying floes and bergs of ice may have formed submarine banks of gravel, and glaciers have produced their "moraines," or terrestrial banks, many a deep

recess or steep submerged valley may have been filled up, either with sand, gravel, or mud mixed with rolled boulders: in short, all the causes which in the present state of the earth are known to co-operate in producing those changes and those results which may possibly become the matter of inquiry to future intelligent beings, did co-operate, in the period now under discussion, to produce the results which have been classed under the general term diluvial, and which are now called quaternary, post-tertiary, or glacial. The term glacial, which has been applied to this formation, is derived from the numerous manifestations of the action of ice over large spaces; in the wearing or striation of rocks, in some cases even on their under or over-hanging surface; in the transport of erratics; and in the apparently sudden destruction of the numerous large animals now peculiar to warm climates, which are found either in the gravel itself or in caves partially closed by it, or frozen up in the ice. And as the general evidence as to climate, according to Dr. Philippi, after balancing the exceptional cases on the one hand with those on the other, indicates little difference between the latest tertiary and the existing epoch, such destruction seems to indicate a sudden depression of temperature which, whilst it destroyed many animals still fitted for warm climates, gave rise to a large extension of glaciers on land, and to a widely extended spread of floating ice on the sea. To throw additional light on this subject every one should examine carefully the gravel in his neighbourhood, and endeavour to discover the locality of the rocks from which it has been produced.

RECENT OR ALLUVIAL.

Having now entered within the still passing period of the earth's history, our object will be to direct attention to those phenomena which, as they can be now studied in their progress and changes, are the more valuable guides to us in estimating the character of the past, since we discover in the alluvial deposits, through many analogies, the mode in which more ancient deposits have been formed. It is now that the action of rivers may be traced, the extension of the deltas at their mouths estimated, and the action of the sea itself observed in all its phases. The processes of destruction and of formation connected with these actions extend over the whole earth, though, as they are necessarily modified by many local peculiarities, the result is not identical but parallel formations, the contemporaneity of which it might be difficult at more remote ages to determine. This class of formations may, from their peculiarities, be divided into mechanical, chemical, and organic, and further into land, fresh-water, and marine formations, the results of volcanic eruptions being connected with each.

Mechanical Deposits. First in Valleys.—Torrents and rivers, in their course through mountain regions, carry along with them a mixture of large and small fragments, torn from the projecting boundary rocks, and deposit their load in the lower and more tranquil portion of their course, as gravel, sand, or mud,—the nature of the deposit being modified in proportion to the strength of the current, as is also the distance to which it is carried; so that the rolled fragments, or gravel, which at a period of high floods are hurried down a considerable distance, are at ordinary times covered with fine sand or mud; and there is therefore in this simple and constantly occurring natural event, an exemplification both of the removal of portions of rocks from their native bed and their deposition at another, and of the formation of alternating beds of clay, sand, and gravel. When the rivers or streams pass through lakes, or wide expansions, matter is always deposited at their bottom; and when circumstances expose such deposits to view, it is sometimes possible to distinguish between the portions or layers produced in a peculiarly wet season, when the force of the torrent would be in excess, from those of a dry season, and even to separate

the portions deposited in the dry and wet seasons of the same year. When the direction of the river is through rocks rich in ores or in precious stones, the action of its waters often separates them from their matrix, and as the weight of such substances is generally greater than that of ordinary mineral matter, a partial separation is effected, as they remain behind, whilst the finer matter is hurried onwards. On deposits of this kind, which become valuable from the quantity of ore or of gems which they contain, works are established for repeating the natural process, by again washing away the remaining fine matter; and in this manner the weight of the substances sought effects, as before, their separation. Particles of gold, platinum, iridium, rhodium, palladium, osmium, chrome, and magnetic iron, are obtained in the Ural chain of Russia and in Brazil, and of gold in Wicklow and elsewhere; the term stream gold or stream tin, etc., being applied to such products. As yet, platinum has only been obtained in this secondary manner, and the greater proportion of the gold is similarly procured, as well as a considerable part of the tin, whilst the zircon of Bohemia, the chrysoberyls and hyacinths of Ceylon, the diamonds of Brazil and of the East Indies, are due to similar separation and deposition; so that mankind is indebted to these newer operations for much of their direct wealth, as well as for that which springs from the fertility of the soil, restored by the overflowing of rivers charged with mineral matter, as in the well-known case of the Nile. In Borneo, gold has been found mixed with alluvial matter in limestone caves. The gravel of the Rhine is estimated by M. D'Aubrée to contain an amount of gold equivalent in value to 165,828,000 francs, or £6,564,025; but what is this compared with the vast quantity of gold sent from the diggings in Australia and California, amounting, between August 1851 and December 1856, to upwards of 12,500,000 oz., which at £4 per oz. gives £50,000,000 sterling from Australia alone? The amount from California being most probably even greater, though the gold is not quite so pure.

Deltas.—Where rivers discharge their suspended mud into the sea, and where the coast is shelving, and there is no powerful marine current, a delta is often formed by the deposition of mud at the point where the waters have lost their transporting power. This class of deposition usually commences at the centre of the river's mouth, and an island is first formed, which goes on extending and widening till a triangular space is occupied by the deposit, the apex being directed upwards, and the base facing the sea; and this peculiarity of form having been first specially noticed in the mouth of the Nile, the deposit assumed the name of Delta, from the Greek letter of that name. Sometimes, as in the Nile and the Rhine, several islands are simultaneously formed. so that the delta is finally a compound one, and is separated by various channels. The delta of the Ganges is still more remarkable than that of the Nile and Rhine, its perpendicular depth from the apex to the base being about 180 miles, and therefore exhibiting a formation comparable in extent to many of those of past geological epochs.

From the action of the Sea.—As the rivers, so does the sea itself effect a change in the form and position of the land with which it is in contact; for, whilst at one point its waters encroach and carry away, at another they deposit and increase; and as they contain from three to four per cent. of various mineral salts (as chloride of sodium, chloride of magnesium, sulphate and carbonate of magnesia, sulphate and carbonate of lime), their resulting formations are often more fixed and solid than those of fresh water. This is specially the case in warm climates, and as the fragments of shells are often mixed with the deposits, as well as comminuted portions of calcareous rocks, there are sometimes formed sandstones, sometimes limestones, sometimes conglomerates. It is in such a formation at the Island Grande Terre, near Guadeloupe, that human remains have been imbedded; and there cannot be a doubt

that many such are in progress below the waters of the sea, and only to be brought to light by such upheavals of the coast and sea bottom as that which affected so strikingly the coast of Chili.

Chemical Deposits.

Calc Tuff and Calc Sinter, or Travertin.—Where mineral waters come to the surface, and as they pursue their course along it, by the influence of light, air, evaporation, loss of temperature, absorption, and escape of carbonic acid, a mineral deposit is thrown down. Springs charged with lime yield in this manner calc tuff, or sinter, which, according to the researches of Gustav Rose, assumes the form in cold springs of calc spar, and in hot springs that of arragonite. Calc tuff is usually a porous mass, but sometimes its layers are sufficiently firm to be used in building, and are then valuable from their lightness. The most remarkable example of such 'Travertin' formations is to be found in Italy, and so rapid is the progress of deposition, that at the Baths of San Filippo, a mass 30 feet thick has been formed in twenty years. These springs are made use of to procure stone casts, the lime being deposited in a firm and solid state on models immersed in the water. In Hungary, calcareous springs have created for themselves banks of calc tuff, the peaks of which project and look like craters. Such tuff is sometimes rendered still more friable and porous by enveloping moss and leaves, and in other instances, although soft when fresh broken, it becomes, on exposure, a hard building stone, as at Jena.

Siliceous Tuff, or Sinter.—Thermal springs deposit, on cooling, much of their silex. The hot springs of Iceland, and especially the Geyser, are of this description. At intervals of a few minutes, a lofty column of hot water is thrown up, and then a dense fog overspreads the surrounding ground, and from this condensed and cooled spray the silex is deposited in the porous form of tuff, or sinter, whilst, in the interior of the basin, a species of opal is formed. Several springs which deposit silex are found in the Azores; and it is very probable that semi-opal and hyalite, which are found frequently in Germany in the crevices of basalt, and, in short, most of the siliceous minerals which are so abundant and so beautiful, in connection with that formation, have been formed in a similar manner by the filtering away or the absorption of the water by which the mineral matter had been originally dissolved.

Bog Iron (*Limonite*).—Ferruginous springs or waters deposit a brownish-red scum of peroxide of iron on their banks, or, when they pass through boggy or marshy districts, form what has been called from such localities bog or marsh iron. When the waters contain also much silica, it will likewise be deposited; and as sand or gravel may be also mixed up with and consolidated by the mineral matter, a variety of ironstone is formed, which has been called sand ore.

In Sweden, bog ironstone has been fished up from under the sea, where, according to Hausmann, it still continues to be produced, and it would be interesting to compare the microscopic structure of this ore with that produced in fresh water. The presence of phosphoric acid in bog iron ore, so unfavourable for smelting, is probably consequent on the decay of organic bodies in the water during its formation.

Deposition of Saline Bodies.—To the chemical class belong the saline deposits which are thrown down by some springs, streams, and lakes, and generally they are not very extensive. From the mineral springs of the Baths at Vienna, a fine powder is precipitated, which consists of gypsum and muriate of lime. In the South of Russia, several lakes annually overflow their banks and deposit a saline crust; but this phenomenon is much more common in the lakes, and especially in the very low grounds, of the warmer zones. In six small lakes near Terrareh in Egypt, soda has in this manner been deposited in large quantity. The extensive turf moors at

Franzensbad, near Eger, are partly coated with a white saline crust of sulphate of soda (Glauber salt) and sulphate of iron, which is now turned to a profitable use. Some salts exude out of the rocks, especially in cavities, as is the case with saltpetre, nitrate of potash, or nitre, in a remarkable degree, in the limestone caverns of Brazil and of Ceylon.

Mineral Oil, or *Pitch*.—In several parts of the earth are springs of a mineral oil, which on drying becomes either asphalte or a species of coaly mass. The Carpathians and the vicinity of the Dead Sea are rich in these springs, as is the island of Trinidad, where there is a complete sea of asphalte. In Germany, at Brunswick, several asphalte springs have more recently been discovered. Another locality is the island of Zante.

Organic Formations.

From the action of Plants or Animals—Turf.—This description of formation is rightly connected with geognosy, as it is in some instances covered by recent mineral deposits, and in others exhibits a passage into the brown coal, which is a constituent part of the earth's crust. Turf consists principally of an accumulation of marsh and water plants, especially of various species of moss, the lower layers of which have in succession died, and through the action of humic acid been changed into a peculiar brown, felted, slimy, and combustible mass. In some of the layers of turf, the remains of plants are so decayed and changed that their original condition can only be inferred, but in others the actual species of the moss can yet be determined. In some bogs, the growth appears to have ceased, whilst in others vegetation is still vigorous on the upper surface. In Alt-Warmbrücher moor, near Hanover, cutting for the second time, the turf has been re-formed, according to Leonhard, in fifty years, and during the last thirty years a layer from 4 feet to 6 feet thick has been in course of formation. At Franzensbad, near Eger, a similar fact has been observed, the exhausted turf hollows having been again filled with new turf plants in from ten to twenty years, which are formed into useful turf in from fifty to one hundred years. The great bogs of Ireland are amongst the finest examples of this kind of formation, both as regards their extent and depth; and although no very detailed or satisfactory observations have been made on the new growth of bog in old exhausted hollows, where drainage and cultivation have not so modified the conditions as to stop it, a very slight observation is sufficient to show that the first step of the accumulation of moss plants can yet be traced. Keferstein has remarked that turf formations are rare on calcareous and frequent on siliceous bottoms; but Ireland is against the generality of this observation, as turf is abundant in some of the limestone districts, and has in several cases grown over lacustrine deposits of shell-marl. Thick beds of turf occur on the summits of some high hills in Ireland and other countries, where a clay bottom retains the moisture. On the banks of the North Sea, a species of turf is formed from accumulations of seaweed. Large masses of bog have sometimes been detached, and become floating islands, one of which on the Gördauer Lake, in Prussia, was so large as to support a hundred head of cattle, until, in 1707, it was broken up by a severe storm. Sometimes turf is found below the high-water level of the sea, as at Greifswalde and Geageland, on the East Sea, and in an interesting example on the north coast of Ireland, near Portrush, the elytra of beetles (fresh and bright) occur between the layers of turf. Turf is also formed in the warm zones, as at San Paulo in the Brazils. In the Irish bogs, the roots, trunks, and fragments of the branches of large trees, both oak and fir, are abundant, and in several instances, two or three successive sets of the roots are observable, standing upright one above the other. As before observed, turf exhibits a connecting link between the existing epoch and the next preceding it. It is sometimes very compact, full of iron

pyrites, which frequently induces spontaneous combustion and the formation of sulphates; often contains fresh-water shells; and is covered by layers of sand and clay, thus exhibiting a passage to the brown coal. In Langensalza, a bed of such turf with stems of trees was found under a covering of 12 feet of sand and 7 feet of earth. At Wittgendorf also, near Sprottau, in Silesia, turf resting on fresh-water marl is covered with sand and gravel.

Submarine Forests.—On various parts of the coast of Great Britain and of the North of France, are found the remains of ancient growths of trees and plants in positions below the level of the sea, though they are of species still living. These become visible sometimes from the encroachment of the sea on the coast, and at other times simply by the ebb of the tide, whence their name. They probably owe their present position to a partial depression of the land. A very beautiful example of such remains of trees has been brought forward by Colonel James, R.E., being a discovery made whilst excavating the splendid new steam basin in the Portsmouth Dockyard. On the western coast of Jersey, General Lewis has noted a fine example of such forests.

Coral reefs and Islands.—They occur in the Pacific and Indian Oceans and in the Red and Mediterranean Seas. The formation of ancient limestone hills has been explained by reference to these reefs and islands, in the supposition that great masses of rock were thus built up from the bottom by the continued growth of polypes enveloped in their calcareous coverings,—and that such masses of coral rock covered the sea bottom; but recent researches, especially those of Quoy, Gaimard, and Ehrenberg, have shown that the growth of coral does not continue in great depths, and that coral reefs or islands are only incrustations on the inequalities of the sea bottom, whether formed of mountain masses as yet not elevated to view, or of banks of detritic matter, and are therefore not generally more than 20 feet or 30 feet thick. Whilst, then, such formations explain the true nature of coral reefs of ancient epochs, the great masses of limestone could only have been formed by coralliferous zoophytes during a gradual subsidence of the earth's crust, by which the surface was kept at the proper depth for their successive growth. The habits of coralliferous zoophytes explain also those deposits of shale with calcareous layers of corals which form so large a portion of the carboniferous system.

Infusoria.—Ehrenberg has discoverd that whole masses of rock consist of little else than infusorial remains, as in tripoli, polishing slate, and kieselguhr. Sometimes the infusoria which have formed these strata belong to extinct and sometimes to still living species, so that the microscope completes the reasoning based on the contemplation of higher organisms. The siliceous skeletons of these minute beings are specially accumulated at the bottoms of marshes and stagnant waters, as in the turf moor near Eger, where a large quantity of kieselguhr and thick beds of a white siliceous powder have been formed, both consisting of the unmixed siliceous portions of still existing infusoria. Many of these infusorial substances, such as tripoli, polishing slate, and kieselguhr, have been classed with metals from their general appearance, but their true character is now well known. Most of the infusorial deposits probably belong to antecedent epochs, but that of Eger is evidently recent, and doubtless there are such in all those countries where the waters flow over much decomposing siliceous rock. It is unnecessary to enumerate the various animal remains which have been dug up in bogs or found in alluvions; but the remains of man's works should be noticed. In Sweden, on digging the canal which joins the Mälar to the East Sea, the four walls of a fisherman's hut, with its fire-place and fragments of coal, were found under 50 feet of sand and mud, which is explained by Lyell by a depression of the land. A wooden bridge made by Germanicus in his German war

was found under a bog; and in Galway, as stated in the tabular view, a hut and paved passage were found under about 30 feet of bog, by the late Captain William Mudge, R.N.

CONNECTION AND EFFECTS OF IGNEOUS, AND SPECIALLY OF ERUPTIVE ROCKS, ON THE EARTH'S CRUST.

In the preceding pages, this branch of geological inquiry has been frequently referred to, and in the tabular views of rocks and of formations the connection of the igneous with the stratified has, as regards time, been pointed out. The present object is to trace briefly the results of that connection in modifying the earth's crust.

In its general appearance granite is very distinct from recent lavas, and yet, by the intervention of rocks which form a sort of mineral passage, granite, syenite, greenstone, and basalt are linked into a chain which connects the ancient with the modern igneous rocks.

The great extension of the granite group over the surface of the globe indicates that its appearance is due to some very general cause; and in like manner the frequent co-existence of granite and metamorphic rocks indicates that both are related to such great modifying cause. In the Erzgebirge at Geier the granite has forced itself up, in three blunt hills, through the mica schist, which in its vicinity has been further changed into gneiss; and in the county of Cavan, in a similar manner, rounded hills of granite occur amidst an ancient metamorphic schist. In the former case the granite has evidently been protruded subsequent to the deposition, and even to the partial metamorphism of the schists; but the exact epoch of its protrusion is not determinable. In the granite of the valley of the Neckar, near Heidelberg, however, though its antiquity cannot be settled, there is a limitation upwards, as it has been laid bare by the denudation of the new red sandstone which had once overlaid it; and such examples as these prove the repetition, at various epochs, of the action of elevating forces, by which the surface of the earth was disturbed and igneous rocks forced upwards. Confirmatory of these views, granite exhibits itself in two forms, either as forming mountain masses, or as veins. The veins are of various thicknesses, from a few inches to several feet, and it frequently happens that massive granite is penetrated by veins of granite differing from it in constitution: thus, Leonhard has called the one, principally porphyritic from the presence of disseminated felspathic crystals, mountain granite; and the other, which is not porphyritic, vein granite. Granite, by acquiring hornblende, sometimes passes into syenite, and distinct veins of granite are frequently observed traversing syenite. In the Odenwalder, the syenite is traversed by many granite veins, but a vein of the syenite in the granite has not as yet been observed, so that it has been assumed that the syenite is older than the granite. The frequent connection of granite with gneiss and mica schist brings it more in relation with the metamorphic processes, whilst the passage of syenite into greenstone keeps up a similar relation between the ancient and modern eruptive rocks. Another instance of such relations may be also cited in granulite or weiss-stein, where compact felspar becomes the principal constituent; for although this rock sometimes assumes an independent massive form, and in veins traverses granite, it must be considered a member of the group which includes the trachytes or felspathic lavas. The veins of granite, granulite, and syenite, often contain large fragments of gneiss and other schistose rocks, and the strata adjacent to these masses are both much contorted and greatly metamorphosed. At Meissen and Hohnstein in Saxony, the granite even overlies the quadersandstein, but it is supposed that this is owing to disturbance: at Christiania in Norway, and in the Harz, it is found between the layers of primary schist and limestone, which it has penetrated by veins, changing

the schists into a species of hornstone; and such examples might be multiplied from many such districts.

Greenstone.—This rock, brought so closely into relation with the granite group by the intervention of syenite, approaches in like manner very near to the basaltic on the other hand, so that it affords a connecting link between them; but whilst granite and syenite exhibit only very obscure examples of intercalation or even superposition to stratified deposits, greenstone is often so closely connected with both the non-fossiliferous crystalline schists and the primary schists, not only occurring in intruded masses and penetrating veins, but also in beds alternating with the regular strata, that it was by Werner classed with them. Where the schistose beds are penetrated by greenstone, the strata are often much contorted, and the structure becomes intricate, affording thus another analogy with decided igneous rocks; and where the two classes of rocks are disposed in regular and parallel strata, distinct transition from one to the other can frequently be observed: but this is not always the case, as in some instances, especially where a thick bed of limestone occurs, the separation between the two is very distinctly marked. It is thus that, reviewing the various circumstances connected with this rock, the more decided metamorphic theorists consider it an ultimate result of metamorphism, whilst the eruptive theorists connect it with erupted rocks, considering the alternating beds as the products of so many distinct eruptions. The more general aspect of this rock is characterized by knoll-like or conical masses, and these are sometimes recognized at a distance as small lump-like excrescences projecting above the stratified deposit. The columnar structure is rare. The close resemblance between syenite and greenstone makes it desirable to have some rules for distinguishing them. Those of Cotta are as below.

Syenite.	*Diorite or Grünstein.*
The dark green hornblende, blended with the yellowish or red Labrador felspar and weathering nearly together, both form on the surface an iron-shot crust.	The mostly white albite weathers sooner than the dark green hornblende, so that the crystals of the latter project above the weathered surface.
Colour.—Reddish or whitish green.	Green, approaching to black.
Occasional Ingredients.—Almost constantly small brown crystals of titanit, and sometimes quartz and mica.	Iron pyrites and magnetic pyrites (simple sulphuret of iron).
Fissures, lined with epidote.	Also common.
Forms.—Massive and angular, and constitute mountain masses.	Conical: knolls, masses, small masses, layers, or veins.

It may be mentioned that, as in granite, minerals and metals are sometimes extensively developed in this rock,—a remarkable example of which may be cited from the neighbourhood of Schwarzenberg, where it penetrates the mica schist, by layers more or less parallel to the stratification; though such arrangement is sometimes so widely departed from, that, combining the divergence with the evidence of fragments of the adjacent rocks taken up by the greenstone, it has been suggested that the igneous matter has been forced into the fissures which have taken place in the natural lines of lamination of the strata. Some of these conformable dykes are more than 30 feet thick, and the ore is so abundant as even to conceal the original composition of the rock. The ores are especially magnetic pyrites, iron pyrites, arsenical pyrites, tin ore, black and brown blende, lead glance, and silver; and the minerals are garnets, vesuvian, chlorite, epidote, tourmalin, prase, mica, calcareous and brown spar, and many others. Granular limestone and dolomite occur in connection with this rock, as in other examples.

Serpentine is allied to greenstone, and exhibits similar physical features. Its veins penetrate the crystalline schists, as well as granite rocks, and it appears to have been protruded amongst the beds of the Jura formation, being abundant in the Alps. Serpentine veins in marble are a curious example of metamorphic action, as indicating diffusion rather than penetration, and cannot be connected in many cases with any great mass. The fissures and cavities of serpentine are often covered with asbestos.

Porphyry Group, including felspar porphyry, pitchstone porphyry, and augite porphyry.—These rocks all affect a similar physical character, appearing in lump-like masses and projecting dykes into granite, crystalline schists, and various stratified deposits. They frequently appear as isolated hills amongst other rocks, and have been noticed in all parts of the earth. Felspar porphyry, including hornstone and claystone porphyry, forms extensive masses, and also dykes of great length, which frequently contain fragments of the rocks passed through, and are sometimes bounded by a breccia formed by their action upon them. The pervading form of this group of porphyries is rather angular than round, and tabular beds and columns are common, so that there is a close analogy in structure to basalts. Metallic veins are rare in the porphyry itself, though more frequent at its contact with schists; in the Tharander Walde, the main mass lies between gneiss and clay slate, and dykes from it ramify through both. At the 'Zeisigsteines' it becomes columnar, and at the Esberge still more so. The overlying rock is here the 'Quadersandstein,' in which there is an analogical resemblance with the similar porphyry in the county of Antrim. Between Freiberg and Frauenstein, dykes many miles long cut through the gneiss, and are themselves penetrated by metallic veins. Pitchstone porphyry, including pitchstone and pearlstone, is comparatively rare, and is usually connected with other porphyries, which it either penetrates in mass or by dykes: it occurs in Saxony, in Hungary, and extensively in the island of Arran: it appears also in the felspar porphyry district of Antrim.

Melaphyr, (*augite porphyry*, *augite rock*, *etc.*)—This rock is sometimes amygdaloidal, and generally appears either in small knoll-like masses or in irregular dykes, penetrating massive and schistose rocks, and effecting important changes in the fossiliferous deposits. The varieties of this rock are very numerous, as it becomes porphyritic from detached crystals of augite, of mica, or of felspar. Its bladder-like and amygdaloidal structure, and the occasional existence of columns, approximate the rock to the basalts.

Basalt Group, including clinkstone and trachyte.—This remarkable group brings up the working of ancient igneous forces to the very threshold of the existing epoch. In basaltic countries, isolated conical hills are common; such independent knob-like masses of all sizes from 5 to 1000 feet in height, and from 10 to many thousands in diameter, projecting above the surface of the country, and sometimes being connected together in one great mass. The basalt is sometimes like a stream of lava spread over other strata, and it is frequently found alternating with them: it has penetrated through all the ancient igneous rocks and through all the fossiliferous strata up to the post-tertiary, and some of its varieties often intersect others. Where basaltic dykes have crossed other rocks, remarkable chemical and mechanical effects have been produced; granite gneiss and mica schist have been reddened, and (especially the mica) partially melted; clay slate, burnt and hardened; sandstone, reddened, glazed, and reduced to a columnar structure; stone and wood coal, charred; limestone, frequently reduced from an earthy or compact to a crystalline state; shale, changed to jasper; fragments of underlying beds, raised to a higher level, and the regular strata, disturbed and uplifted, though not to the same degree as by granite

and porphyry, the chemical exceeding the mechanical effects on this class of rock. It is in basalts that the columnar structure becomes most striking, and wherever a deep section can be observed, as on the northern coast of Ireland, highly columnar beds will be seen associated with others purely massive, and the several beds separated the one from the other by beds of ochre and of amygdaloid. The columns are of various forms, the pentagonal and hexagonal prevailing; and they are often, as at the Giant's Causeway, beautifully jointed: they appear sometimes, on the face of a bed, like long rows of closely arranged pillars; at others they radiate from a central axis, and in dykes they are frequently horizontal. The bladder or bubble-like cavities of basalt, and specially of amygdaloid, have been filled with a great number of beautiful minerals, including the whole family of zeolites. The magnitude and beauty of basaltic dykes are frequently brought to more marked observation by the striking contrast between the nearly black colour and the mason-like aspect of the dyke, and the lighter hue of the stratified rocks through which they pass, or by their independent appearance, projecting like walls above the surface when the softer strata have been worn away.

Phonolith (clinkstone and clinkstone porphyry) and trachyte are not so widely spread as true basalts. Passages between clinkstone and trachyte may be traced, and, where they occur in masses, the larger are generally more of trachytic, and the smaller of phonolithic character. The columnar and tabular forms of structure are observable, as well as dome-shaped or conical hills. Trachytes, occasionally varying to phonolith, occur in the well-known Siebengebirge, in Hungary, in the South of France, and extensively as Andesite in the Andes. As true lavas assume the basaltic and trachytic forms, it may reasonably be assumed that, excepting in the exhibition of craters, basalts and trachyte are strictly analogous to such lavas, and therefore bring the igneous rocks up to the existing epoch.

VOLCANIC GROUP.

Volcanic products are found in every region of the earth's surface, some of which have proceeded from volcanoes now extinct, and the rest from those still in action; and so closely are these products related to those of the basaltic and trachytic group, to which they are sometimes also placed in near proximity, that it would be scarcely possible to distinguish them, were it not that in the ancient groups craters are wanting, as also those substances which have been thrown up from them by eruptive force, such as ashes, lapilli, etc. This indicates a remarkable difference of circumstances; and as the evidence of geological formations has proved that numerous oscillations must have taken place, the dry land of one epoch having been submerged, and when covered as a sea bottom by new deposits, again elevated to the surface; the absence of craters cannot be accounted for by supposing that no sub-aerial eruptions took place in these remote epochs, but rather by supposing that the craters were in part obliterated and filled up when submerged, and in part are yet hidden under the sea; whilst, on the other hand, it may be assumed that sub-aqueous eruptions are in like manner now proceeding, which will be made manifest hereafter, when elevation has brought up the present sea bottom, and exhibited its basaltic and trachytic non-craterierous rocks. Modern observers have indeed thought that they could trace erupted products, like those of sub-aerial volcanoes, amongst the ancient strata; but such proof of the existence of volcanoes it is evident is not indispensably necessary. Volcanic products are divisible into lavas, erupted substances projected from the crater into the air, and muddy matter. Lava is of various descriptions, such as basaltic, greenstone-like, trachytic, porphyritic, leucitic, and slag-like. The erupted substances are loose fragments of slag, obsidian and pumice, vol-

canic *bombs*, so called from their resemblance to *shells*, which are sometimes hollow and sometimes have a solid lava kernel within a coating of slag,—smaller pieces of slag called lapilli, and volcanic sand and ashes. The muddy products are trass, tufa, peperino, moja, which are not present in all volcanoes. These substances are of great practical value in the preparation of hydraulic mortar.

The most remarkable extinct volcanoes are those of the Eifel in Germany, and of the Vivarais and Auvergne in France, in which districts numerous craters and lava streams can be accurately traced, as well as the other products of sub-aerial eruptions.

It is unnecessary to enumerate here still active volcanoes, but it is desirable to notice their geological effects, and, in order to comprehend them, to bear in mind that earthquakes in the existing epoch are a portion of their phenomena,—the earthquake often preceding the volcanic eruption,—both being the result of unusual movements in the interior of the earth. It is thus that whilst the streams of lava which flow over the sides, and the dykes which penetrate the walls of the crater, illustrate the more ancient igneous products, the movement of the earth's crust, its upheaval or its depression, and the cracks which fissure it under the action of the earthquake, are equally illustrative of the mechanical effects of former forces of a similar nature. Von Buch has divided volcanoes into central and linear,—the one in which a great central volcano is surrounded by a number of smaller, as in the case of Etna and the Lipari Islands, the other in which they are arranged in a line, as if related to some great crack, as in the Andes, in the Grecian Islands, etc.; and a careful examination of the earth's surface will doubtless show that the modifications of the forms of mountain chains may often be explained by similar variations in the mode of action of ancient igneous rocks, when forced upwards.

In the great earthquake of Chili, 19th November, 1822, the shock was felt along the coast for 240 miles, and by many natural appearances, such as the exposure of beds of shells, and of an old wreck, at times of the tide when they were not before so exposed, it was ascertained that at Valparaiso the uplifting amounted to three, and at Quintero to four feet; and when it is considered that the great chain or axis of disturbance along which the volcanoes are arranged is at a considerable distance, it may be surely assumed that the intervening country had been raised in a much greater degree. There are also traces of more ancient shocks by which the coast had together been raised about 50 feet. The rocks of the coast are granite and syenite, in which there are numerous parallel cracks which can be followed landward for a mile and a half. The effects of this earthquake could be traced over a space of 100,000 square miles.

An earthquake shook violently part of Wallachia on the 11th January, 1838, and was very instructive, as many parallel fissures were formed, and then filled by matter forced upwards.

The earthquake which destroyed Lisbon, 1st November, 1755, was felt in all Europe, so far as Norway, on the north coast of Africa, in several of the West India Islands, and by many ships at sea. At Lisbon, an adjacent hill was split in two, and the new quay sunk 600 feet below the water. The changes of level of the celebrated Temple of Puzzuoli, near Naples—the rising and sinking of the land in Scandinavia—the appearance of islands forced up—are all phenomena which exhibit the still continuing action of elevating forces. Jorullo, in Mexico, affords an example of volcanic action combined with extensive elevation, and Skaptaar Jokul, in Iceland, one of a stream of lava which may vie with many of the ancient basaltic streams, being about 50 miles long, 12 miles wide, and on an average 100 feet thick; whilst a stream of lava from the great volcanoes of the Island of Owhyhee was in motion for nearly

twelve months. The contemplation of such wonderful effects of causes still acting, may well prepare us to estimate those of forces which acted according to the same laws in former epochs. Whilst, therefore, the action of water has been generally to wear down, transport, and re-deposit in nearly regular and horizontal order, or, in other words, to restore the level of the earth's surface, the action of heat has, in conjunction with electricity, etc., tended to disturb that level, and to raise some portions of the surface above others. Such an elevation could not be effected without much disturbance and the formation of cracks, though the general result might admit of much modification. Where, for example, the elevating force acted on a point or small space, an isolated mass or mountain might be formed, and the cracks would radiate from a centre; or should the superficial pressure be diminished, the crust might be raised like a great bubble, and, finally separating at its apex, form the circular wall of what Von Buch calls a crater of elevation: if acting on the line of a crack, either one side might be uplifted, and thus form a steep precipice overhanging a plain,—an appearance not unusual in nature,—or both sides may be uplifted, so as to form two precipices, with a valley of elevation between them; and again, if cracks are formed transverse to others, and upheaving takes place, there will be various modifications of the primary ridges. These forces continuing to act at intervals for ages, have produced the great and the cross chains of mountains. Von Buch, pursuing these inquiries, observed that in certain districts the mountain chains, the strike of the strata, with some modifications, and even the great valleys, had certain predominant directions; and Elie de Beaumont, extending Von Buch's researches, founded upon them, in 1830, his Theory of Elevation, according to which *all mountain chains of the same age have also the same direction.* He assumed that the earth's crust has been elevated into mountains at various periods by forces acting at all places in parallel directions; and to determine the relative ages of such upheavals, appeals to the undisputed fact, that uplifted and highly inclined strata must have been in existence prior to the upheaval, and horizontally deposited strata overlying the inclined, must have been formed subsequently to such upheaval: so that it became evident that mountain chains had been formed at very different times, and that the epoch of their elevation must have exercised much influence on the direction and grouping of sedimentary deposits. M. Elie de Beaumont has in this manner distinguished about fifteen systems of elevation, according to their age and direction, and of which the most remarkable are the twelve following.

1. *System of Westmoreland and Hundsrück.*—Direction of elevation, N.E. ¼ E. and S.W. ¼ W. No newer strata than the Silurian, and probably a part of Devonian, uplifted. This includes the Eifel, the Taunus, the Isle of Man, and South Shetland. 2. *System of part of the Vosges.*—Direction, E. 15° S.—W. 15° N. Mountain limestone, but not the coal-bearing strata, uplifted. To this belong the hills of Bocage, in Calvados. 3. *System of the North of England.*—Direction, S.—N. The coal-bearing strata are the most recent affected in this elevation. 4. *System of the Netherlands and of South Wales.*—Direction, N. E.—S. W. The whole of the coal formation affected. 5. *System of the Rhine.*—Direction, S.—N., or S. S. W.—N. N. E. Strata to the Zechstein (magnesian limestone) uplifted. The Vosges, Schwarzwald. 6. *System of Bohemian and Thuringian Forests.*—Direction, S. E.—N. W. The keuper is the newest formation disturbed. La Vendée, Bretagne. 7. *System of the Erzgebirges.*—Direction, S.W.—N. E. The Oolite or Jura, but not the Quadersandstein, affected. Côte d'Or, Mount Pilas, and the Jura in part. 8. *System of Monte Viso.*—Direction, N. N.W.—S. S. E. The older but not the newer chalk affected. 9. *System of the Pyrenees and Apennines.*—Direction, N.W.—S. E. The younger or upper chalk, but not the tertiary strata, affected. This system being parallel to

No. 6, it is often difficult to separate one from the other. Harz, Teutoburger Forest, etc. 10. *System of Corsica and Sardinia.*—Direction, S.—N. The lower tertiaries, but not the upper, affected. The basalt of Hesse. 11. *System of the Western Alps.*—Direction, N. 26° E.—S. 26° W. The newer tertiaries affected. 12. *System of the main chain of the Alps, from Wales to Austria.*—Direction, W.—E., or E. N. E.—W. S. W. A portion of the post-tertiaries affected. Monte Ventoux, Leberon.

Such is the theory as originally propounded by De Beaumont, and it brings down the evidence of successive elevations almost to the existing epoch, but in its application there are many difficulties. Many mountains have evidently not been raised by one impulse, but by many acting at different times and frequently in the same direction; and as the crust once broken becomes easily fractured in the same line, igneous rocks of different ages may often be traced along a line common to several successive elevations; nor can the assumption that the elevations of any one epoch have everywhere been effected in parallel and straight lines, be admitted. To follow out such lines of elevation over the earth's surface, would indeed be most difficult, more especially as the more frequently repeated they were found to be, the more approximated in direction they would become,—a difficulty even perceptible in the twelve great systems enumerated; but even restricting the generalization, it must be acknowledged that the groundwork of the theory is correct, and that its promulgation has had a most powerful effect on the progress of geological science.

As in the formative processes resulting in the deposition of the mineral strata of the earth's surface at various epochs, and the entombment of the relics of successive races of organic beings, so also in the forces operating to disturb the tranquillity of the universe and to render the surface of the earth uneven, or a mixture of hill, valley, and plain, the course of nature has now been traced from the remotest to the still passing epoch, and everywhere, and in all times, the same great causes have been seen to act in breaking up or in re-forming the mineral crust. But it may be still doubted how the great elevating force has been developed; and here indeed a difficulty must be felt in replying, as direct observation can only extend to a mere film of that earth, the surface of which it has affected in so striking a manner. The facts of disturbance are palpable, and the nature of the forces producing them can be inferred by reasoning, though not demonstrated by observation. Electricity may be fairly classed with such forces, and yet it may be only a secondary cause; but assuredly ample reason has been adduced for the assumption that heat must at least be a primary one. This subject has been learnedly discussed by Gustav Bischoff in 1837, and assuming the fluid condition of the central portions of the earth from heat, he demonstrates from physical considerations, that hot springs, the production of massive rocks from the cooling of the fluid mineral matter, volcanic eruptions and earthquakes from the expansive force of steam produced by contact of water with the still heated and fluid internal mass, are all natural consequences of such a condition. When then we look at the earth's surface, we see in it a whole, built up by slow degrees; and it has been the object of geological science to trace its growth through every step of its progress, and to separate the great compound into all its elements, both organic and inorganic.

PRACTICAL APPLICATIONS OF GEOLOGICAL SCIENCE.

In the preceding Sections, frequent reference has been made to practical results, and it has been shown that a correct determination, on theoretic considerations, of the geological position of rocks, is generally most essential as a guide in practical research. The economic uses and value of many of these rocks have been pointed

out; but it is also desirable to bring forward more distinctly the economic importance of the modifications of the surface produced either by disturbance and elevation, or by denudation.

It must at once strike the Engineer, that the proper direction of roads, railways, and canals, though determined proximately by an actual survey of the existing conditions of the earth's surface, has in fact been established by the geological modifications of that surface; and it must therefore be evident, that in entering on the examination of any country for such purposes, a valuable clue to the direction of the lines will be obtained by a knowledge of the prevailing strikes of stratification and of cleavage. And further, it is evident that a knowledge of the dip and arrangement of the strata must be of equal importance in determining the probable nature of the substrata, and therefore in guiding the Engineer as to his lateral deviation, either to avoid solid substances in his deep cuttings, or to arrive at them for his foundations. These aids are important, but the effect of modifications of the surface on the distritribution of water is still more striking, and will be here noticed under a distinct head.

THEORY OF SPRINGS.

Water, perhaps the most important substance in nature, is in a constant state of change and movement, by which its purity and consequent fitness for performing the various functions to which it is destined are preserved. In the ocean, that great ultimate recipient of the larger proportions of the rivers and streams which flow over the earth's surface, the great difference of temperature between the Poles and the Equator causes a continued interchange of the cold and warm streams, the cold flowing below, from the Pole to the Equator, and the warm above, from the Equator to the Pole; and in like manner there is a perpetual movement upwards from the surface of the sea by evaporation, and downwards again by the flow of the water which, having been condensed, falls as rain or snow on the earth, and returns gradually to the great reservoir from which it had proceeded. Simple as the processes are, the result is most important to mankind, as a constant and sufficient supply of this vital fluid in its pure and efficient condition is thus brought everywhere within the reach of organic action, either as springs, as rivers, or as lakes: and when this remarkable circulation is contemplated, we can scarcely wonder at the speculations of Keferstein, who saw in the world itself a living organism. Nor is it only in the mode of general supply, but also in the system of the distribution of water, that the wants of organic beings are consulted: for example, had the surface of the earth continued uniform and unbroken, the rain must have fallen more generally, and instead of being collected into separate channels, have soaked into and saturated the upper strata, inducing a swampy condition of the surface, not probably very dissimilar to that it actually possessed, over large tracts, in the earlier geological epochs. Now, on the contrary, the conjoint actions of elevating and denuding forces have produced chains of mountains, valleys, basins, and all the minor modifications of these three great forms. In the vicinity of mountains, it is easy to study the effect of this arrangement, as a river may be seen one day with its ribbon-like stream struggling along through a wide bed of stones and gravel, and the next, rushing forward an overflowing and turbulent stream, being swollen by the sudden rains which have fallen within the area of its leading or connected valleys, and been thereby collected into one great liquid mass. It will be readily understood by this statement that the more numerous the feeders, and the more closely connected with mountain masses, on the summits of which a very large portion of moisture is always deposited over a comparatively small space, the more sudden will be the rises of the discharging or

recipient river; and an Engineer therefore should provide for such a contingency in constructing bridges in such a locality. A large portion of water is thus carried off directly by running over the surface, but another large portion percolates through the surface to a greater or less depth, in proportion to its porosity. In clayey soils, this passage of the water is very slow, and the surface therefore in wet weather becomes moist and clammy, and in dry, forms a crust fissured by cracks. In sandy or gravelly soils, the passage is very quick, and the surface keeps comparatively dry; but if the soil be not very deep, and the water be received on a more retentive substratum, the readiness with which the moisture is restored by a continued evaporation, prevents an injurious aridity, and in consequence this condition of the surface is more generally favourable for vegetation than an impervious soil. If the sand or gravel be on the contrary very deep, and rests on an inclined surface, it acts as a filter, and whilst the water is entirely and rapidly removed, a general aridity of surface is produced. These considerations naturally lead to a perception of the true theory of springs, which will now be further illustrated in detail.

1. It has been seen, that whilst part of the rain falls on the surface and runs off, as on an inclined plane, another part filters through it; and this latter part, where collected together in any cavity of the less pervious substratum, forms a reservoir of water. Even on the sides of mountains, especially in damp climates, this process is constantly exhibited; and whilst the general surface becomes wet and boggy, numerous springs are seen wherever an inequality has led to an accumulation of water; and these, issuing as scarcely perceptible rills, go on gradually increasing as they join with others, and finally emerge in the greater valley as considerable streams. Such is the most simple and ordinary form of springs, from which, taking into consideration the peculiar modification in each case of the earth's surface, may be derived every other; and it becomes at once evident that springs will become superficial, small, numerous, but very temporary, where the pervious stratum is very shallow and the inequalities of the substratum slight.

2. In addition to the water which forms the superficial springs on a mountain-side, a portion may pass between the underlying rock and the superficial matter above it, whether the latter be a stratified deposit or ordinary detritus resulting from the simple decomposition of the rock itself; or should the overlying deposit be moderately porous, some of the water may pass directly through it to the underlying rock, and in either of these cases reservoirs of water will be formed in any great depression of that rock. This is a case which may be expected to occur in granite and highly metamorphic rocks; and in the former, in which open fissures are rare, whilst superficial disintegration, especially in hot countries, has proceeded to a great extent, it affords the only chance of meeting with deep-seated springs. Colonel Baddeley, R.E., has shown its application in Ceylon; and in two essays on the subject in the 'Colombo Observer,' has explained the principles which there regulate the appearance of springs. The underlying rock is a highly metamorphic hornblendic or syenitic gneiss, the outcropping edges of which have undergone much original modification, and is therefore supposed to form an undulated surface—as in fig. 10 (see next page); the hollows being filled up by a detritus, proceeding, according to Colonel Baddeley, from the simple disintegration *in situ* of the more felspathic surface. From the mere inspection of the figure, it is evident that whatever may be the origin of the matter filling up the inequalities of the underlying rock, the water, either in part percolating through it, or passing between it and the surface of the sound rock, must accumulate in the hollows, and that in consequence it may be necessary to sink at *b* to 80 feet for water, although at *a* it had been found at 40; and further, that should the rock under *b* slope gradually off and become exposed in a valley or on the side of

a hill, the water may all be carried off as quickly as supplied, and produce therefore no permanent spring,—circumstances which render the search for water in such cases very precarious. It may be further added in respect to this example, that a rising or projecting spring can only be expected where the water passing between the detritus and the rock is pent up by them, and thus affords a head of water; as, if it merely filters through, the pressure can only raise the spring to the height at which the water stands at the time in the reservoir or hollow. The other form of this case is, where the hollows of the crystalline rock are filled by stratified deposits (No. 11) of shale and sand. Here, as the shale has been worn away, and the rock denuded at the summit, the water may gain access to the layer of sand (s^1), and produce therefore a spring under the bore-hole (a), the water being held back by the projection of the rock to the left of it. Where the water has saturated the whole of this stratum, it will rise over the projecting rock; but as the stratum is open to the valley below, it will be rapidly discharged, and produce no permanent spring under the bore-hole (b). Again, under both a and b, there will be a second supply of water, due to the sand stratum (s^2); but as these lower reservoirs, from their imperfect connection with the surface, must require a considerable time to fill, their practical value will be in proportion to their actual magnitude, or to the quantity of water previously stored by nature in them.

Fig. 10.

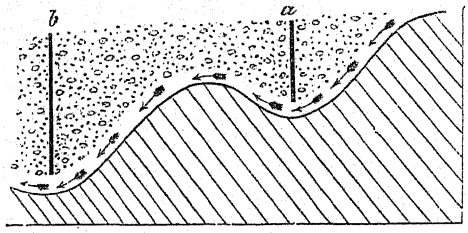
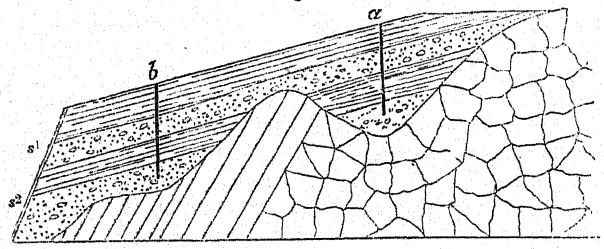


Fig. 11.

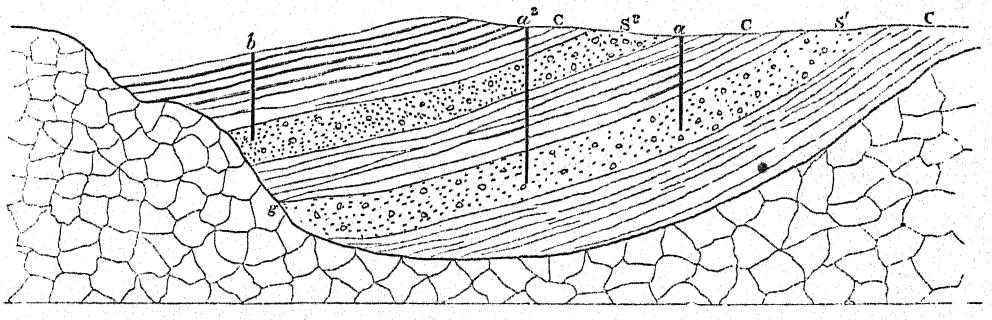


3. In the preceding instances, the accumulation of water has been considered to arise principally from that which flows over the underlying solid rock, but it may be also entirely due to that which enters directly from the stratified deposits, and is merely held back or dammed up by that rock, as in No. 12.

Here it is evident that the supply of water will be in proportion to the extent of surface on which the rain falls, and from which it is directed to the layers of sand (s^1 and s^2), the remaining mass being either clay or some other impervious stratum. If the supply be abundant, the stratum will be kept saturated up to the line of the bore-hole (a), and a constant spring be obtained; but if it be only small and casual, there may be a spring during the rainy season, or whilst the water is making its way

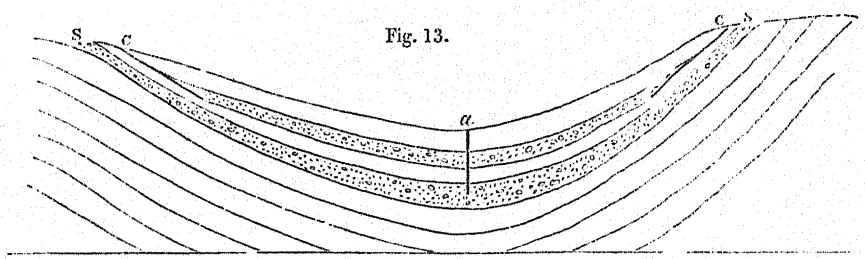
through the stratum, but none at a later period, and the chance of permanency will be increased as the bore-hole is carried nearer to the rocky dam at *g*; and the same reasoning will apply to the upper stratum of sand (s^2), and its bore-hole (*b*): and it may be observed also, that a bore-hole (a^2,) which could only find a temporary spring in s^2, by being carried through the intervening clays, might obtain a permanent one in s^1.

Fig. 12.



This case leads to those where the water is received and thrown up entirely by stratified deposits arranged in the form of basins or troughs; and this may happen either where the basin is produced by an undulation or depression of the underlying strata, or where it occupies the valley produced by the disruption of these strata by elevation; and as some precaution is necessary in reference to this distinction, each case will be considered separately.

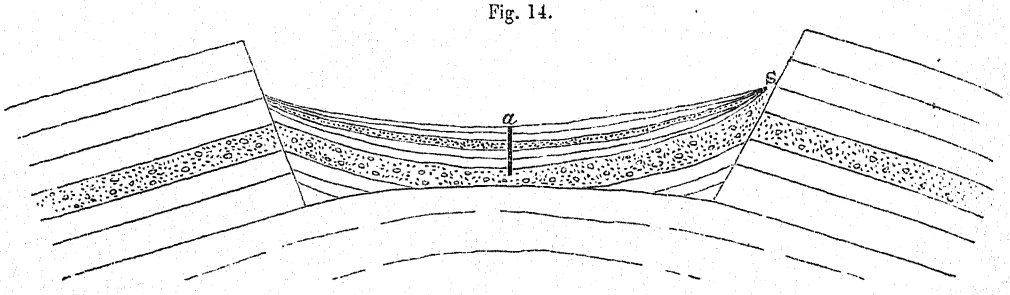
Fig. 13.



No. 13 is the first case, where the strata of sand and clay have been deposited in a basin of undulation, and the water entering the sand stratum (*s*) is prevented from descending by the impervious strata below, and from ascending by the clay above; so that it is pent up in the sand stratum itself. An inspection of the figure is sufficient to show that the nearer the bore-hole is made to the lower point of the valley, the more abundant and secure will be the supply, and the higher the jet from the aperture. If, instead of one layer of sand or gravel, there had been several, the reasoning would be the same, only it might happen that the upper layers had been closed up by the clay passing over them, as in the figure, and therefore be found unproductive of water.

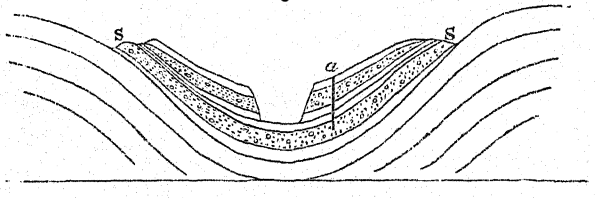
No. 14 is a basin formed within a valley of disruption or even of denudation, or which differs from the preceding only in this circumstance, that the boundary walls, as it were, of the valley may in themselves be partly pervious, and therefore allow

Fig. 14.



the water to escape. If such occur, the water cannot rise above the level of these discharging strata, represented in the figure. And again, secondary denudation may modify the basin deposit, and affect its supply of water, as in No. 15, where it is

Fig. 15.

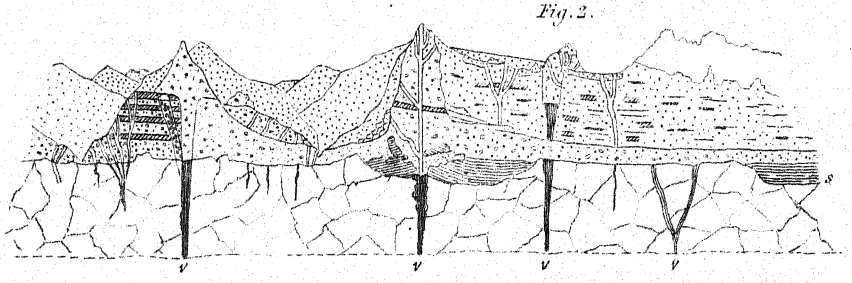


evident that any layers of sand cut through by the denudation in the centre of the basin, must discharge the water they receive at once into the inner valley of denudation, and that no water can be expected until the lower layer, or at least the first layer not affected by the denudation, has been touched by the borer. Faults may also materially affect the arrangement of springs, as in some cases, when filled with impervious matter, they may act as dams, and in others may discharge the water,—so that in boring in the vicinity of a fault, care must be taken to ascertain its condition, and if it be supposed open, to place the bore-hole in the strata dipping *from it.*

It is conceived that these examples are sufficient to guide the Engineer in the application of principles to practice in every case, and he will at once see the great necessity of studying the geological as well as the physical character of the country in which he seeks for water. In granite, and in most crystalline rocks, such a search must be very precarious, as water can only be expected to occur in fissures. In stratified deposits, not metamorphosed, the occurrence of porous alternately with impervious beds brings the principle into operation; and in proportion as the porous beds are looser in texture, as in the tertiary and post-tertiary sands and gravel, and the arrangement of them is more limited by a basin-like form, so will the chance of success increase until it becomes a certainty. A correct knowledge of the stratification at the outcropping of the strata must therefore become a sure guide to the Engineer, and in his boring he will carefully compare the strata passed through with such manifestations of them on the surface, in order to judge whether he has arrived at or passed through any one of them. Should he not be able to find any of these basin-like deposits of looser materials, his pursuit of water in more solid strata must be equally guided by a knowledge of these geological and physical peculiarities; such, for example, as in the chalk and even in the oolite districts, as in such cases the numerous fissures may permit the water to descend, until it is stopped by either a less

THEORETIC SECTION OF THE CANTAL EXPLAINING THE ERUPTIONS OF ITS EXTINCT VOLCANOES

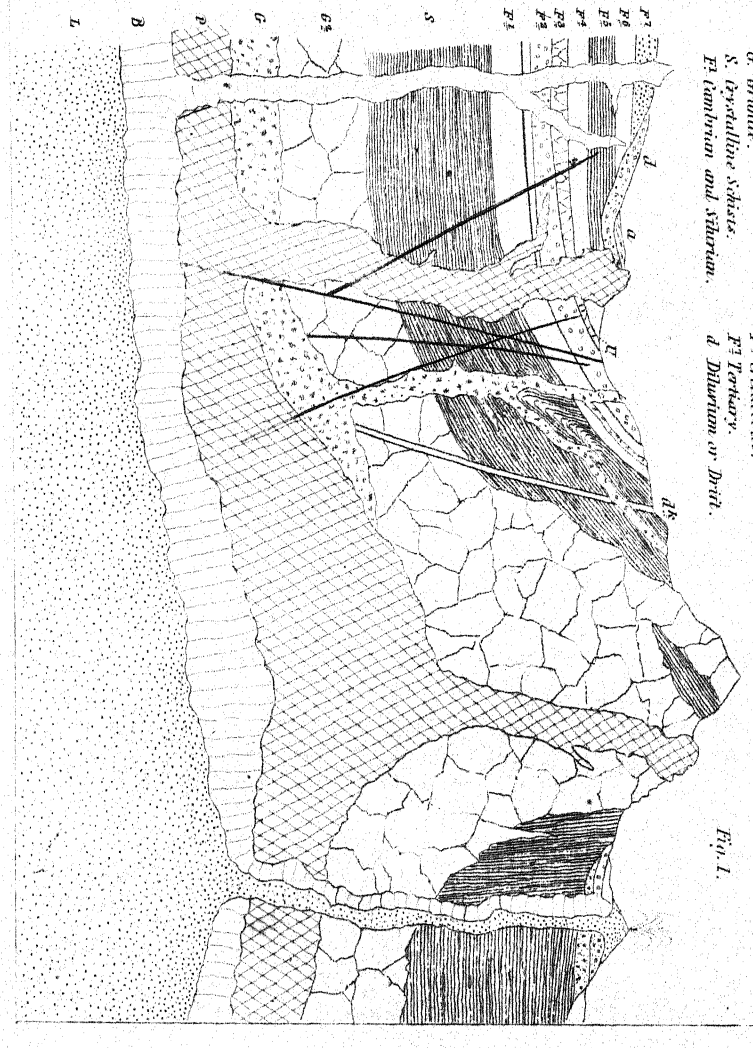
Fig. 2.



v. Volcanic Chimnies.
s. Stratified tertiary deposits resting on Granite.

THEORETIC SECTION OF THE EARTHS CRUST FROM COTTA

Fig. 1.



L. Lavas Ancient and Modern.
B. Basalt.
P. Porphyry.
G. Greenstone.
G². Granite.
S. Crystalline Schists.
F¹. Cambrian and Silurian.
F². Devonian and Carboniferous.
F³. Magnesian Limestone.
F⁴. Trias or New Red.
F⁵. Jura including Lias.
F⁶. Cretaceous.
F⁷. Tertiary.
a. Alluvium
d. Diluvium or Drift.
V. Mineral veins
d². Dyke

J.W. Lowry fc.

London. John Weale. High Holborn. 1848.

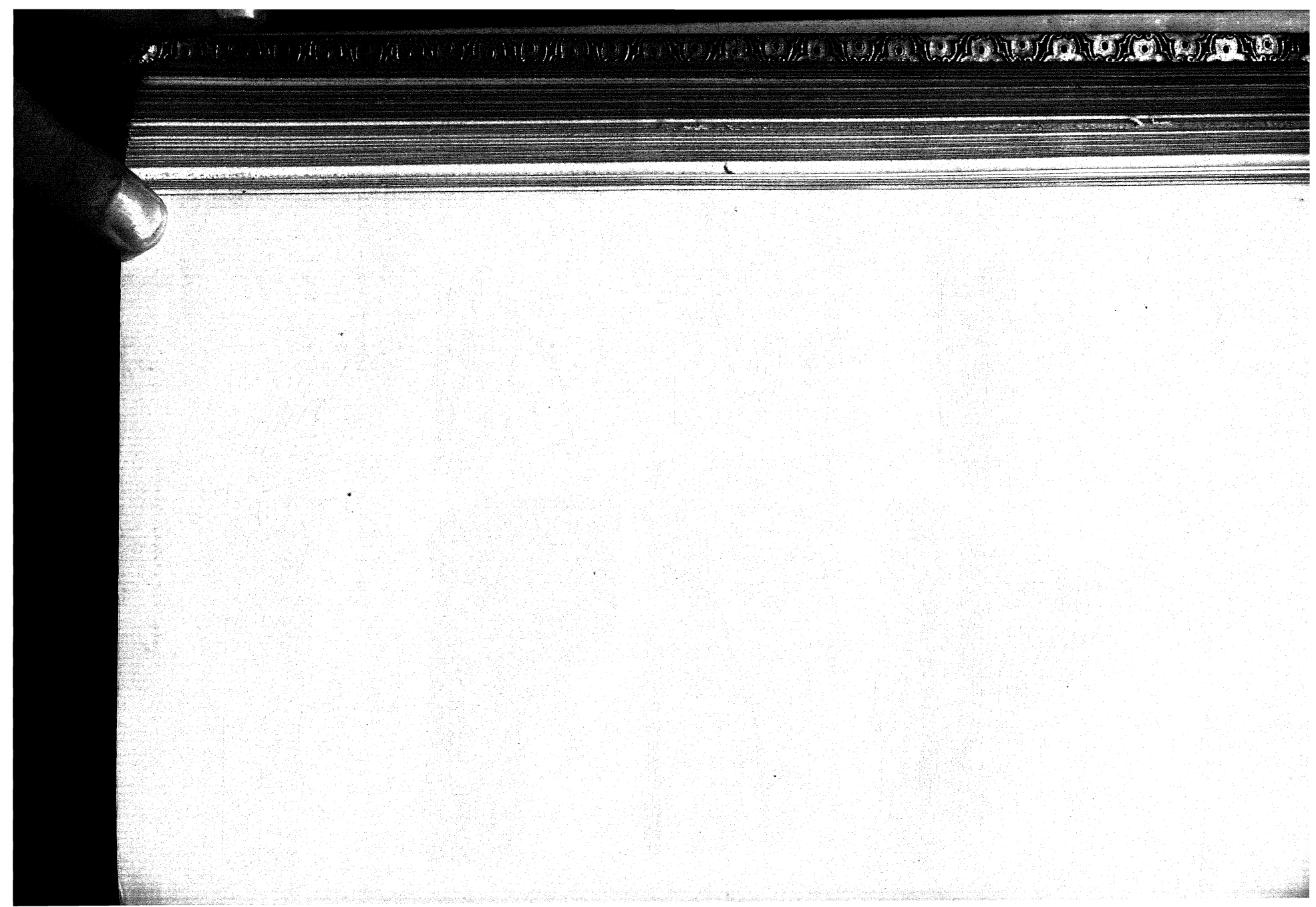


Fig. 3.

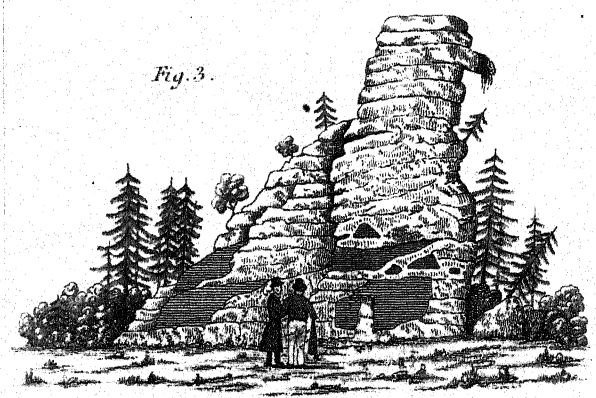


Fig. 4.

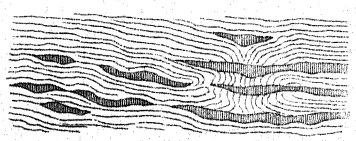


Fig. 5.

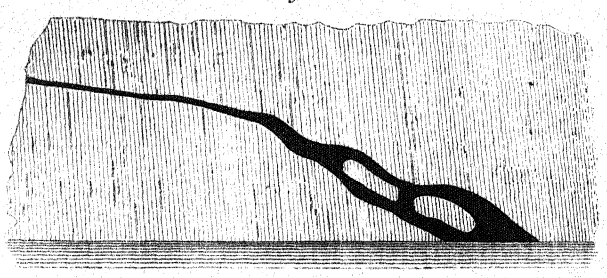


Fig. 10.

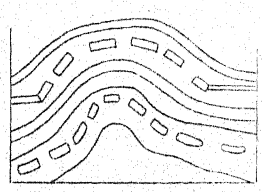


Fig. 6.

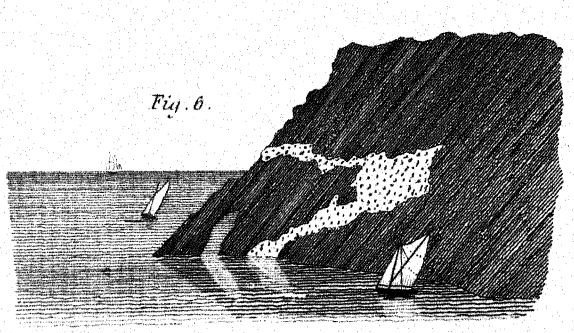


Fig. 9.

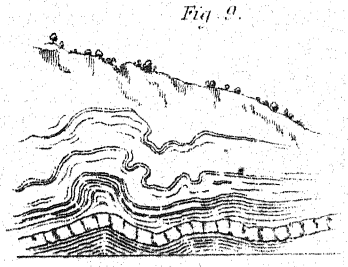


Fig. 8.

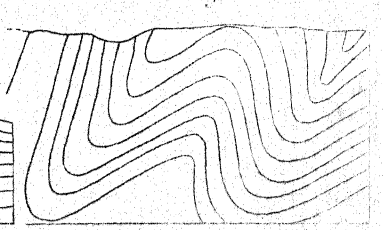
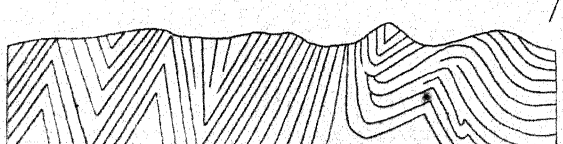


Fig. 7.



J.W. Lowry fc.

London, John Weale, High Holborn, 1848.

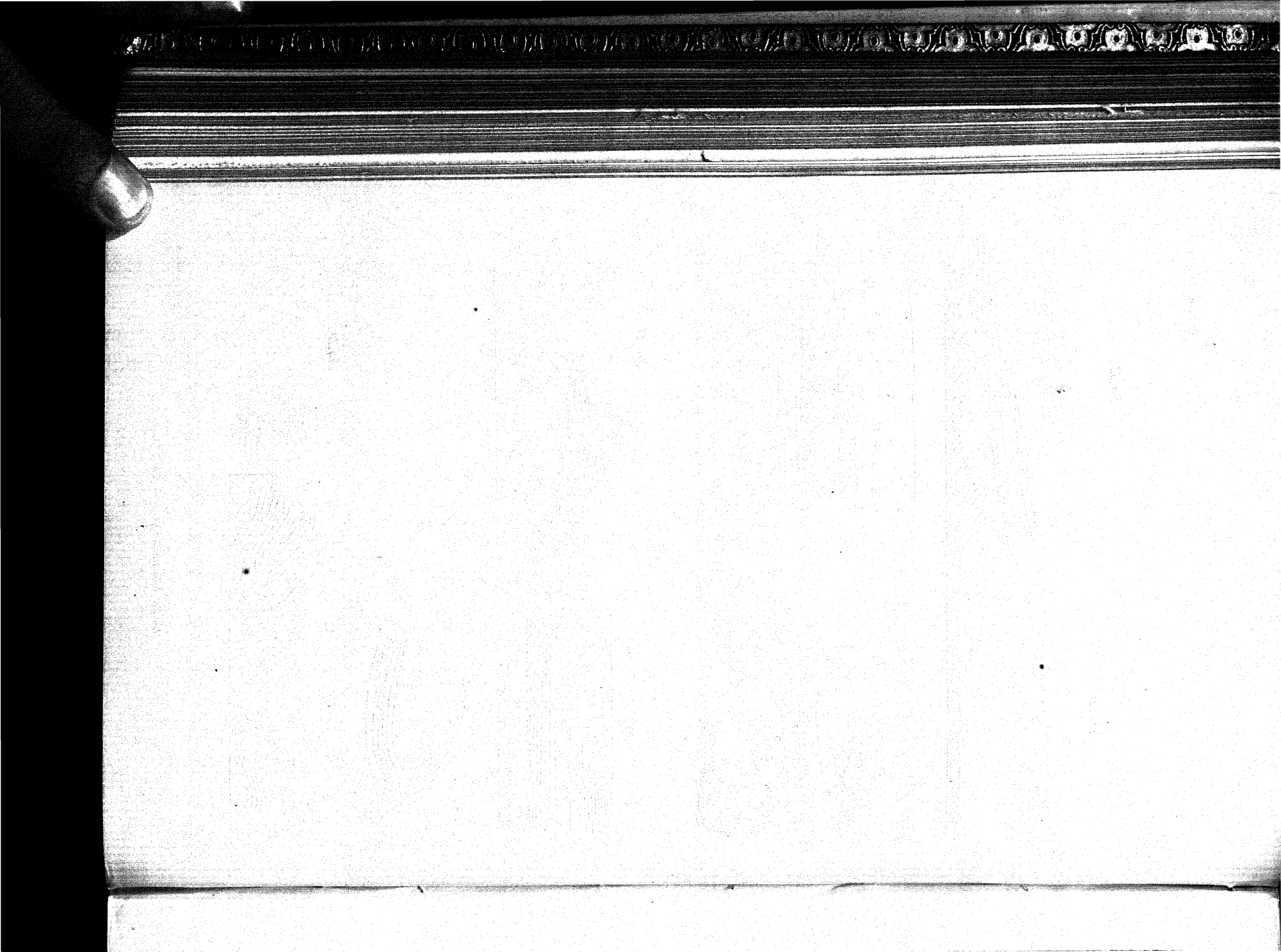


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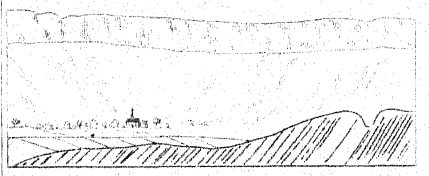


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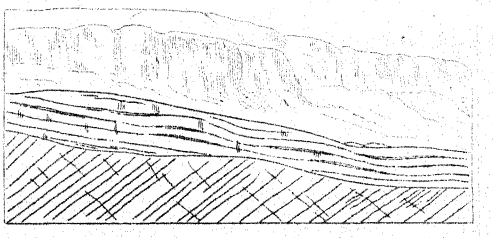


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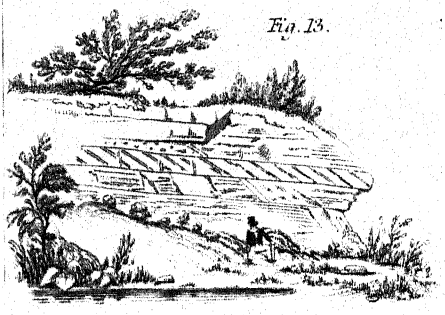


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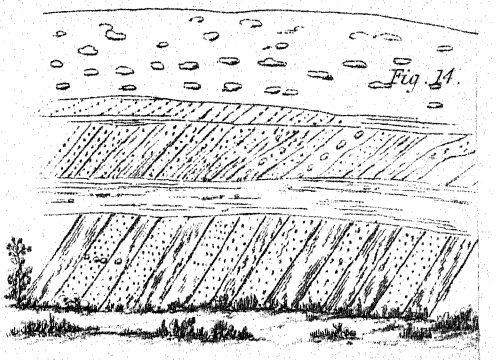


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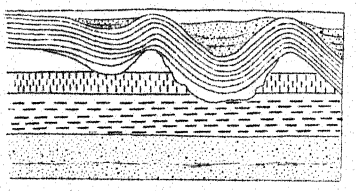


Fig. 17.

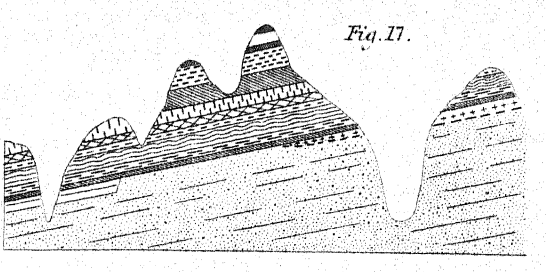


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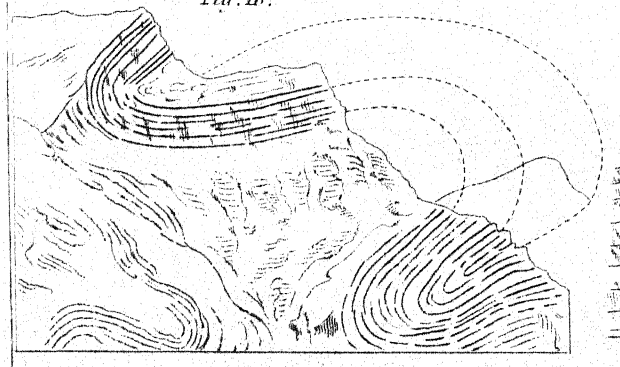
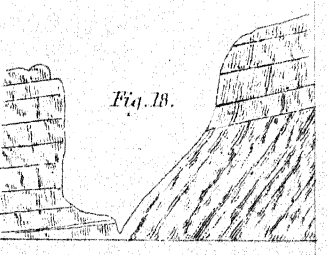


Fig. 18.



J.W.Lowry fc.

London: John Weale High Holborn 1848.

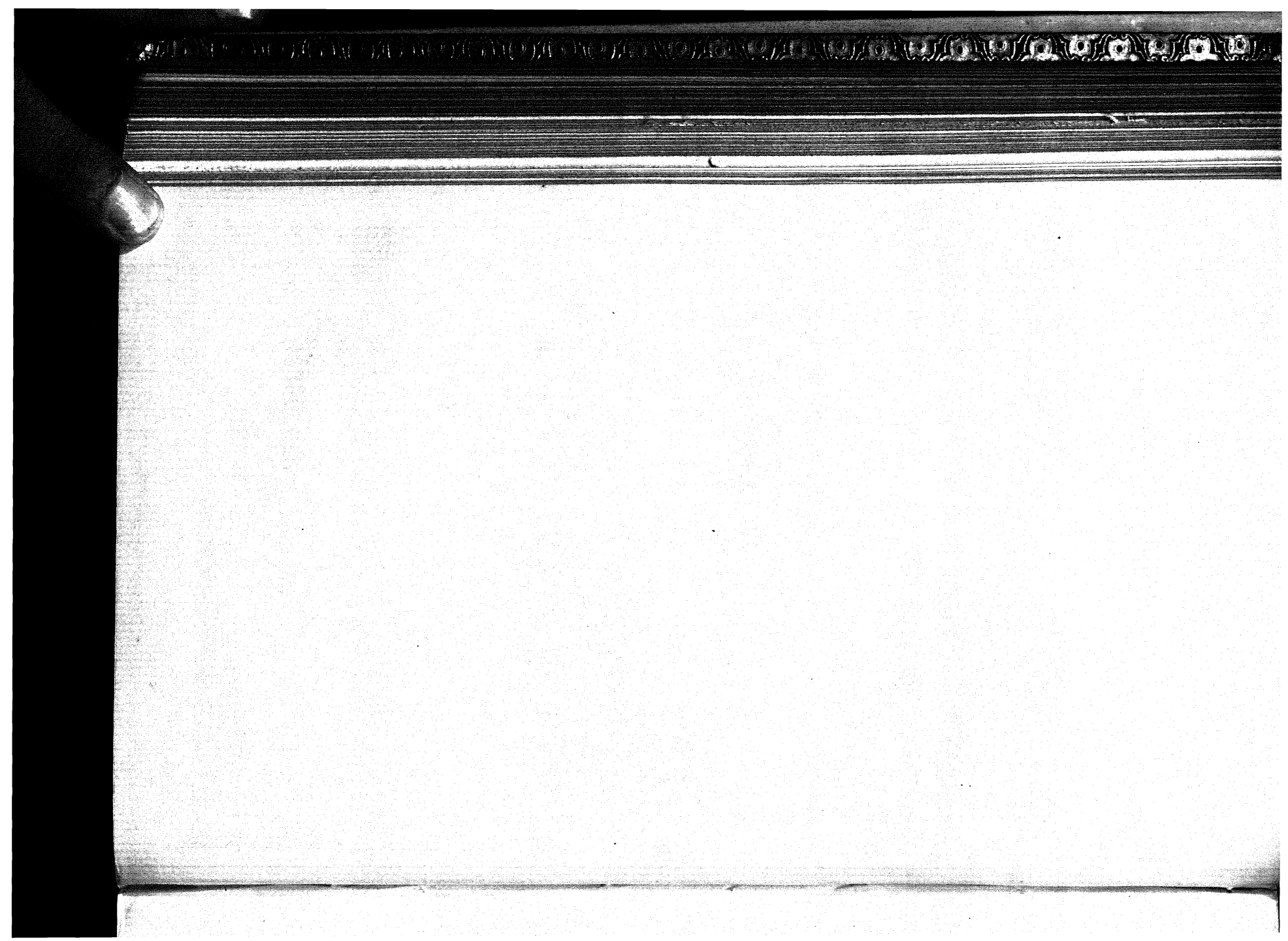


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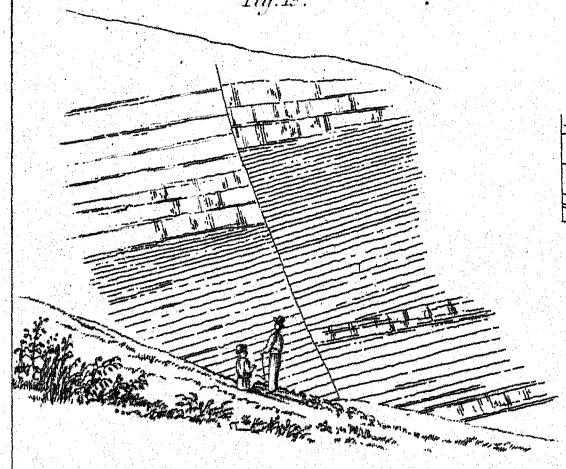


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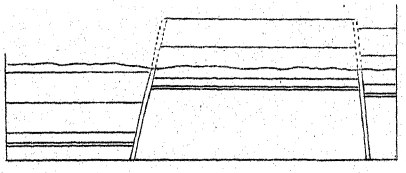
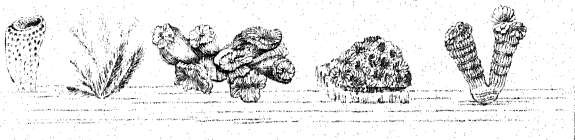


Fig. 21.



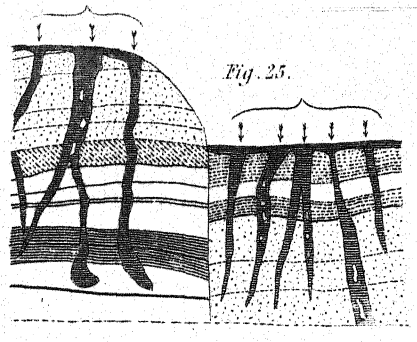


Fig. 25.

Fig. 22.



Fig. 24.

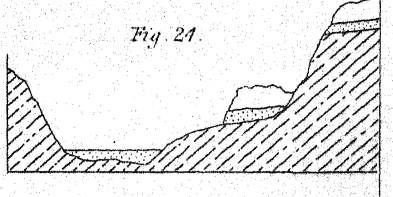
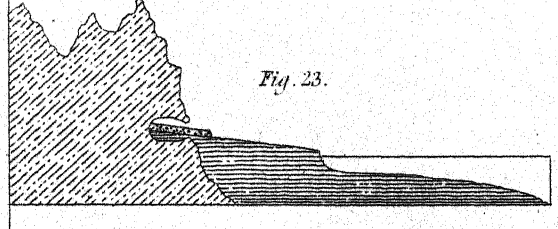


Fig. 23.



J.W. Lowry fc.

London John Weale, High Holborn. 1846.

Fig. 27.

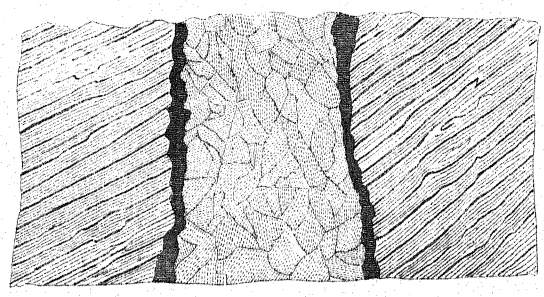


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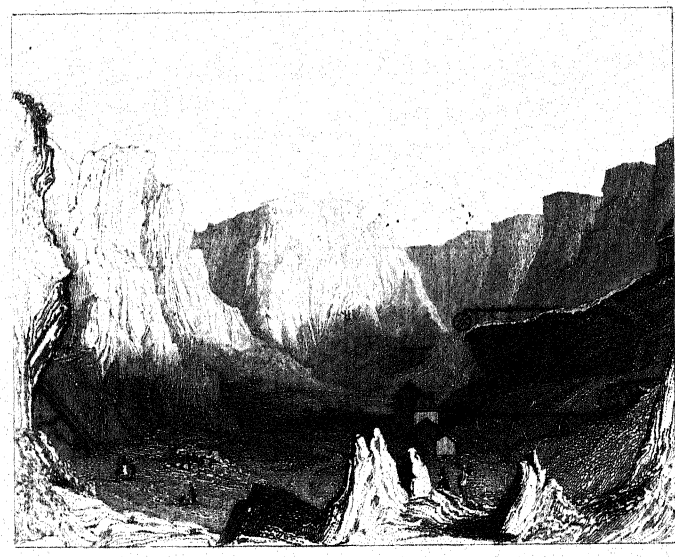
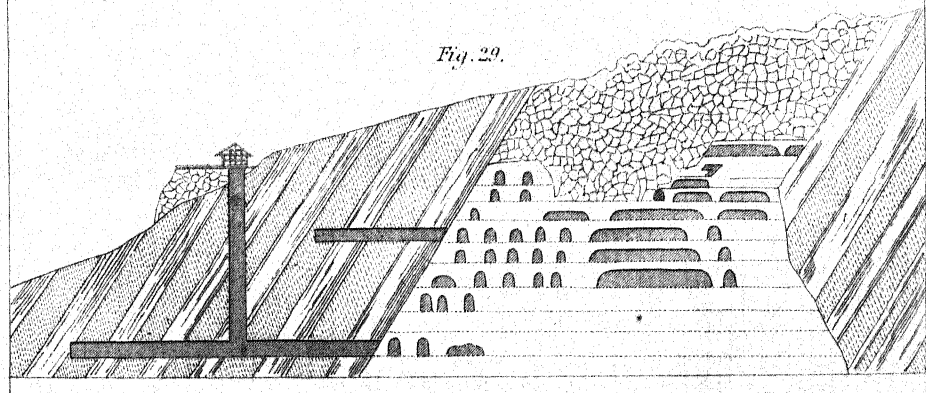


Fig. 29.



J. W. Lowry fc.

London, John Weale, High Holborn, 1848.

Fig. 30.

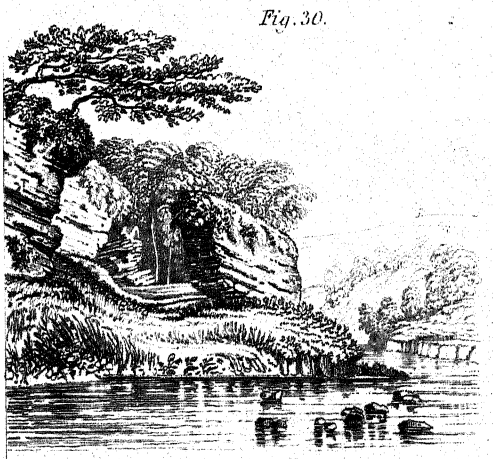
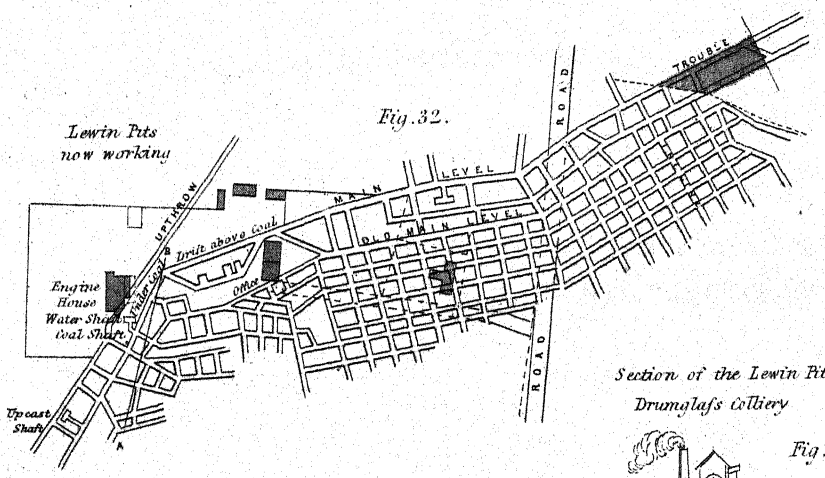


Fig. 31.



Fig. 32.



Section of the Lewin Pits Drumglass Colliery

Fig. 33.

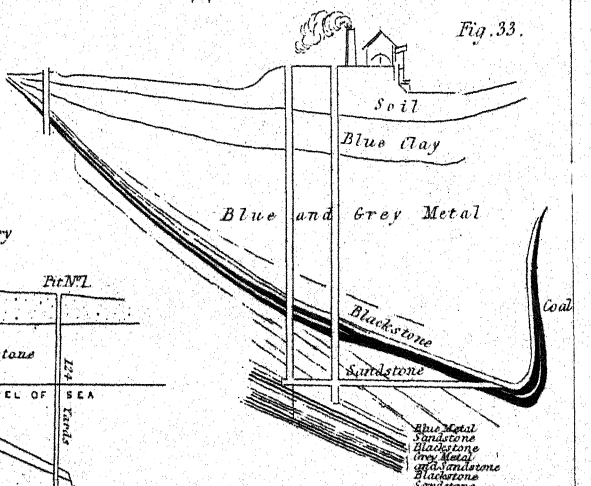
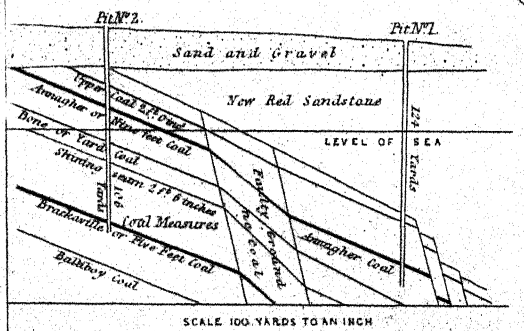


Fig. 34.

Section of Annagher Colliery



J.W. Lewry fc.

London, John Weale, High Holborn, 1848.

Fig. 35.



Angular Erratics resting on Sand Hills at Degaberga in Sweden.

Fig. 36.

Portlocks Clynometer.

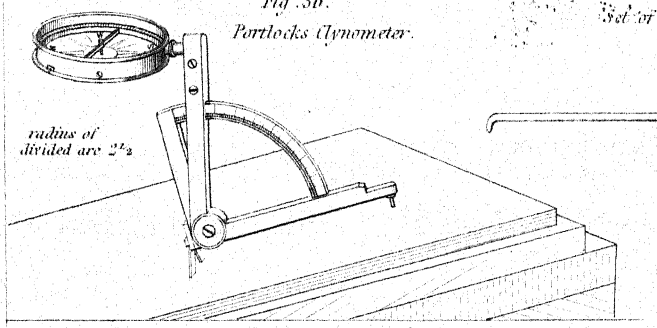


Fig. 37.

Set of Boring Rods.

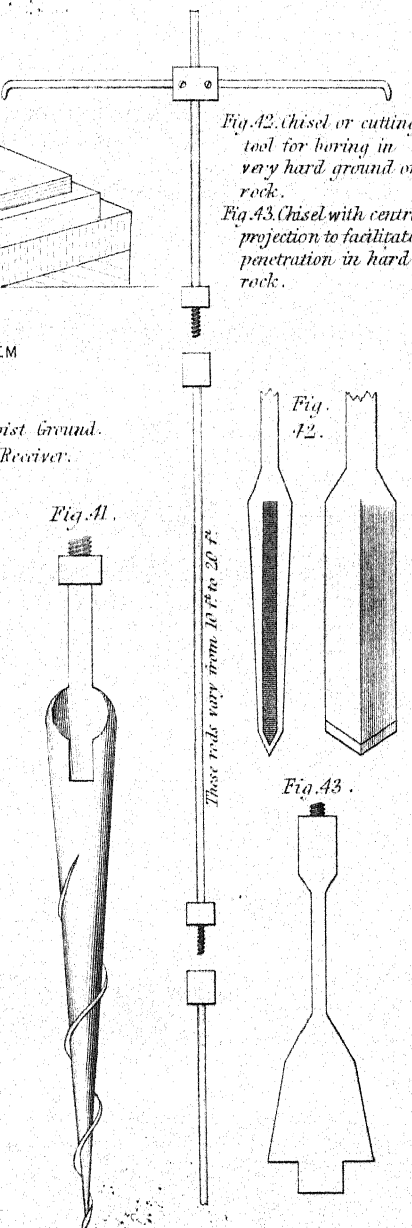


Fig. 42. Chisel or cutting tool for boring in very hard ground or rock.

Fig. 43. Chisel with central projection to facilitate penetration in hard rock.

BORING TOOLS ON THE ORDINARY SYSTEM

Fig. 38 Open Augur for Stiff Clay.
„ *39* Slightly opened Augur for Soft Clay
„ *40* Closed Augur with Valve, for very Soft or Moist Ground.
„ *41* Screw Augur for Hard Ground with Conical Receiver.

Fig. 38.

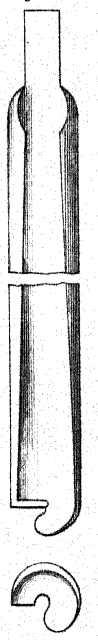


Fig. 39.



Fig. 40.

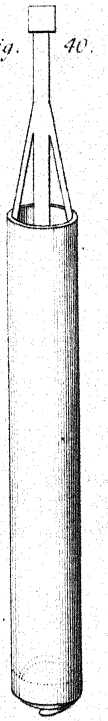


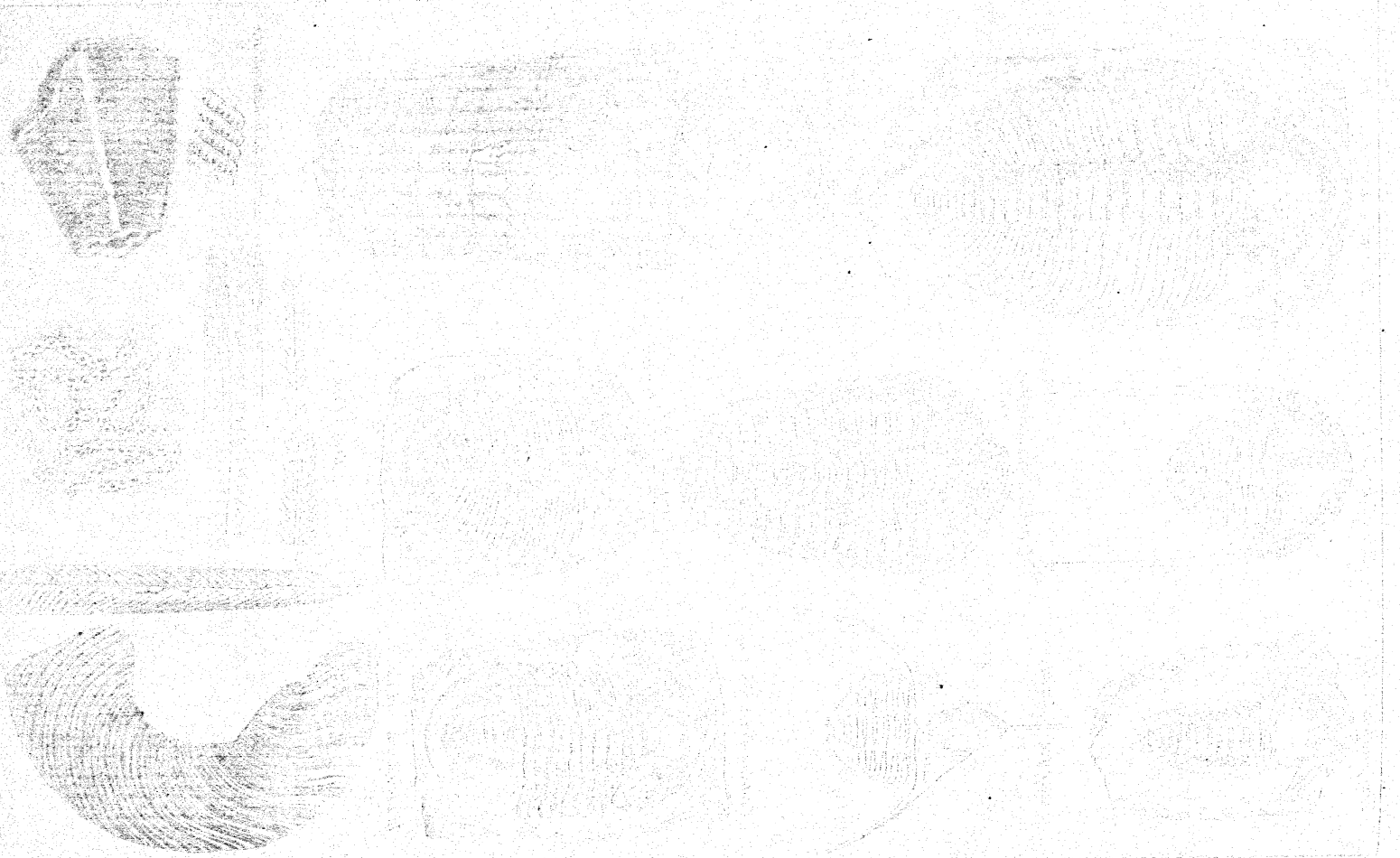
Fig. 41.

Fig. 42.

Fig. 43.

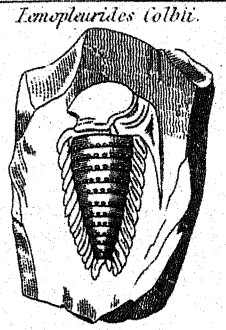
J.W. Lowry fc.

London. John Weale. 59, High Holborn. 1848.

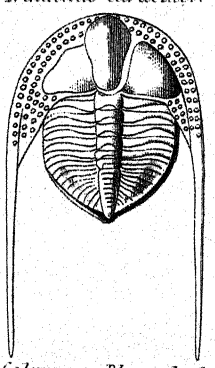


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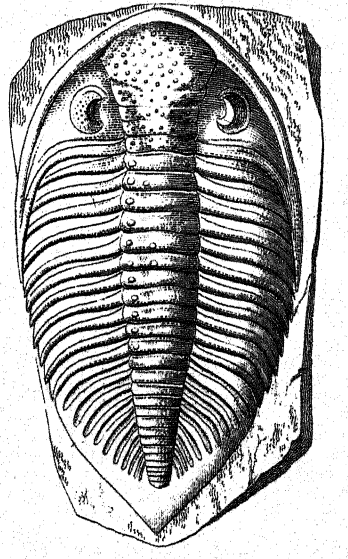
Lemopleurides Colbii.



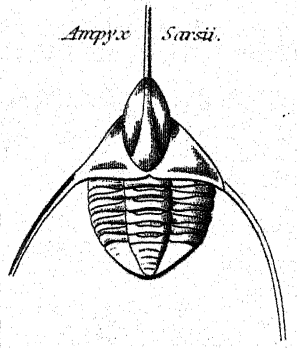
Trinucleus Caractaci.



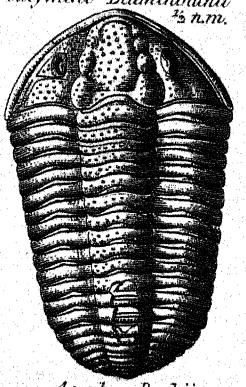
Phacops caudatus ⅔ n.m.



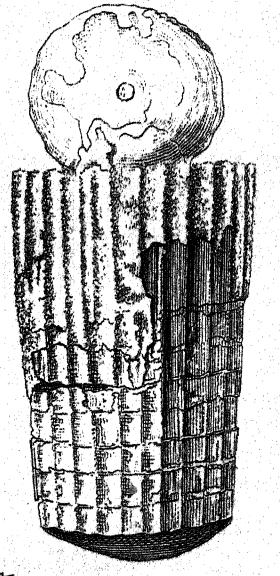
Ampyx Sarsii.



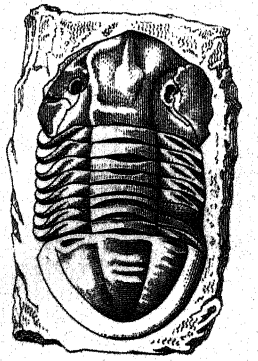
Calymene Blumenbachii ½ n.m.



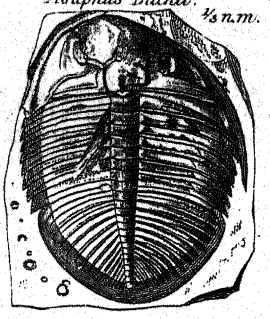
Orthoceras canaliculatum.



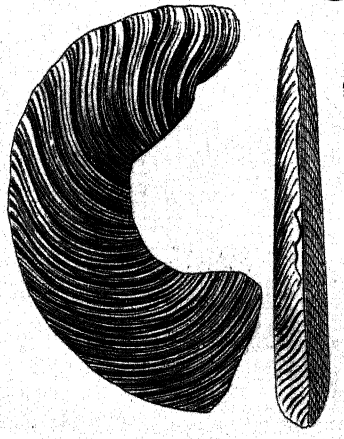
Isotelus Powisii ⅓ n.m.



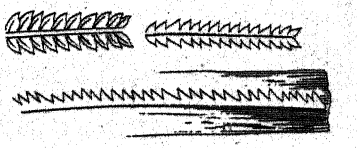
Asaphus Buchii. ⅓ n.m.



Lituites cornu-arietis.

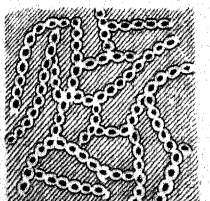


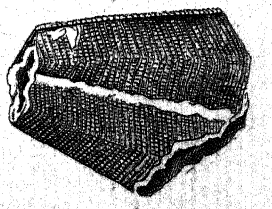
Graptolites



Corallaria quadrisulcata







Catenipora labyrinthica.

J.W. Lowry fc.

London. John Weale 59. High Holborn. 1848.

CHINESE OR PERCUSSION BORING.

FIG.45. FRENCH MODE. *Cyst or double Chisel with intermediate cutting points the earth passes up the grooves of the great impelling weight and lodges in the neck between the projections.*
FIG.46. GERMAN MODE. *The impelling weight is an Iron bar and the earth is received in and brought up by the surrounding cylinder.*

FIG.49. BEARTS PATENT 1844.

The hollow boring tube of Fauvelle arranged as a Syphon the water passing from the Reservoir down the Annular Space and ascending up the tube carrying with it the mud or sand disturbed by the cutter or augur. The small exhausting Pump at top is used to draw up the water so as to fill the pipes at first. The Syphon is formed with watertight moveable joints so as to permit the movement up or down

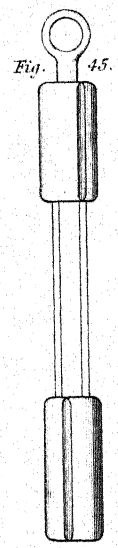


Fig. 45.

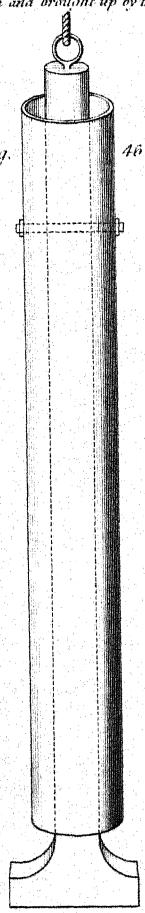


Fig. 46.

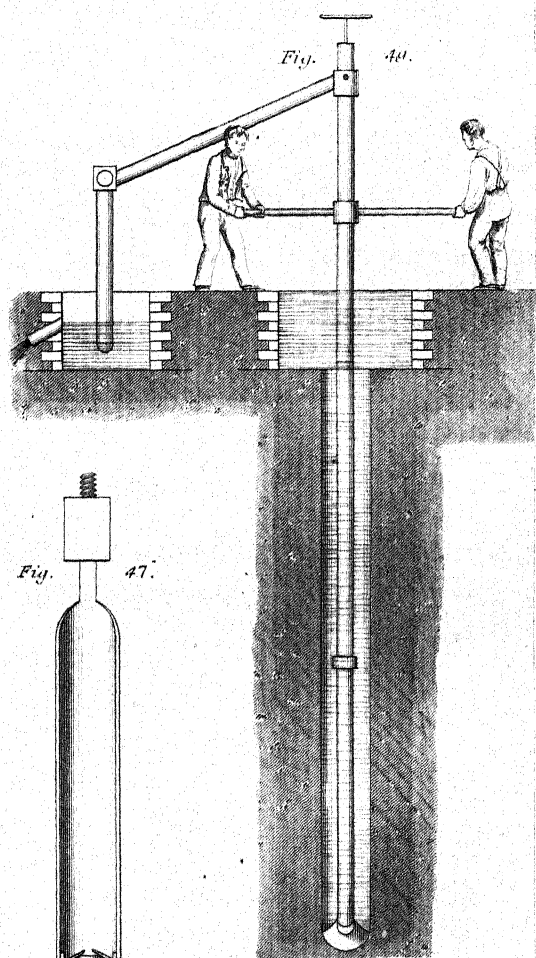


Fig. 40.





Fig. 47.



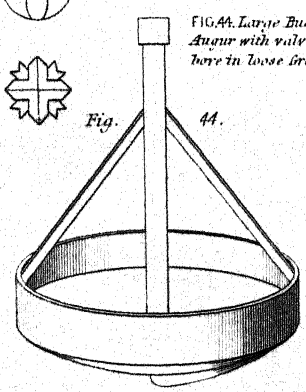


Fig. 44.

FIG.44. *Large Bucket Augur with valve to bore in loose Gravel.*

FIG.47. *Tool to draw up a broken Augur the head pushing back the Catches which then hold it fast.*

FIG.48. *Flemish Tool for enlarging a hole by two cutting Scoops.*

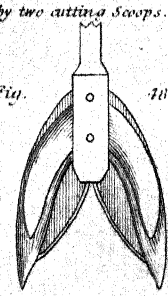
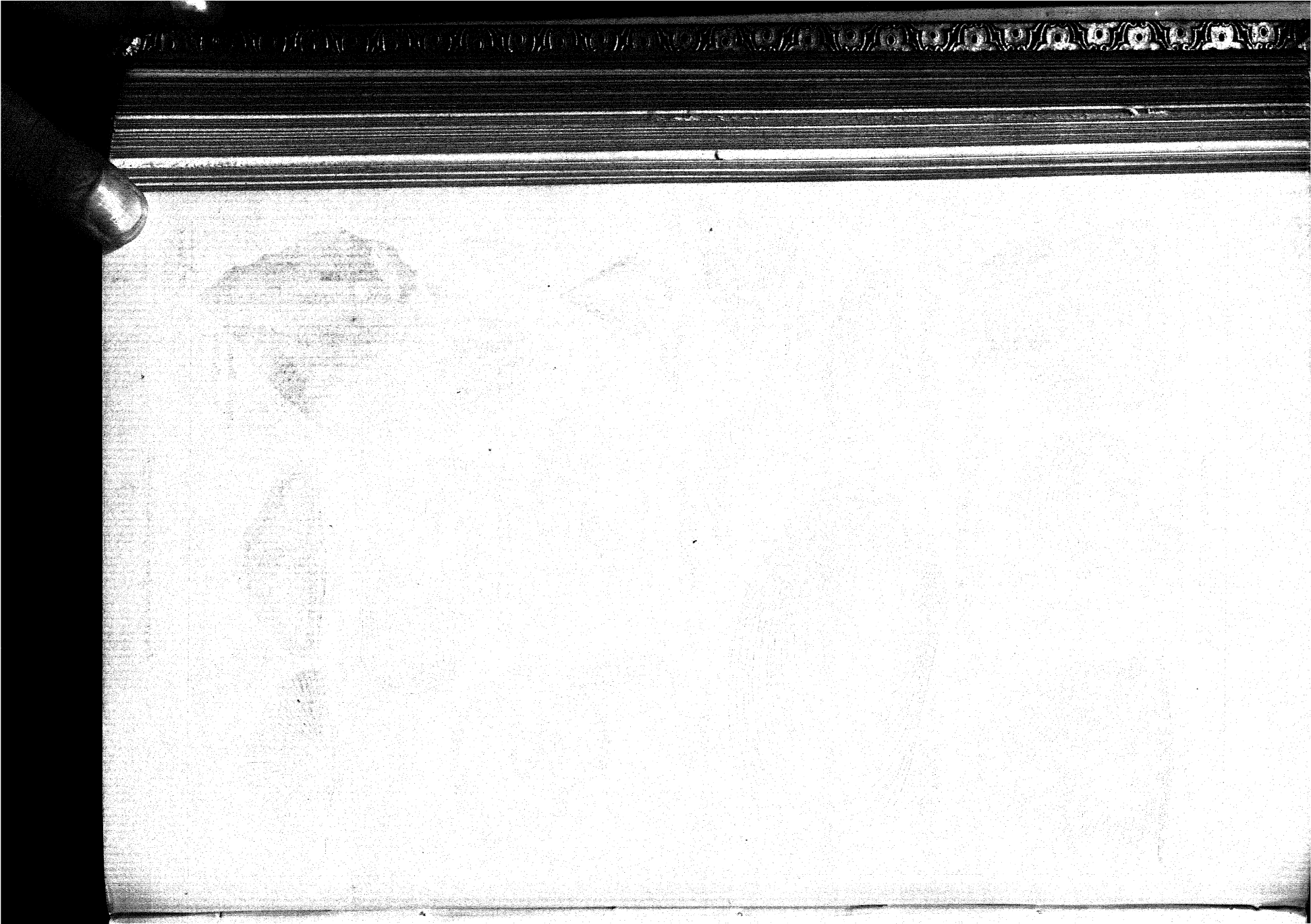


Fig. 48

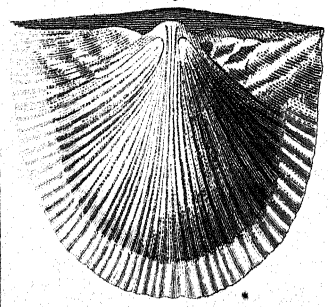
J.W. Lowry fc.

London: John Weale, 59 High Holborn. 1848.

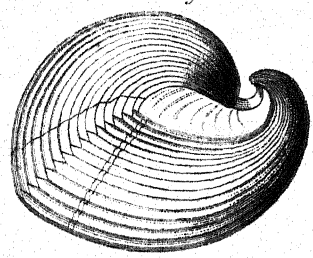


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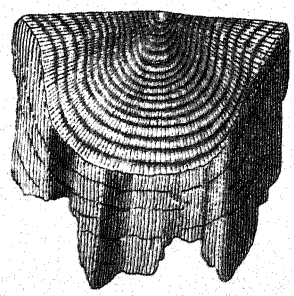
Orthis rugifera.



Pentamerus Knightii.

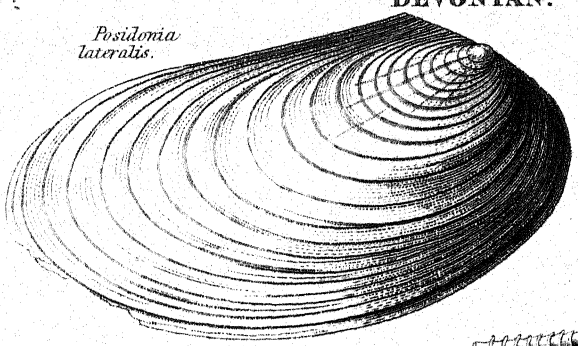


Leptæna depressa.

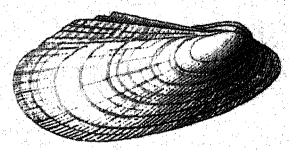


DEVONIAN.

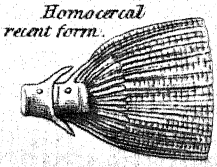
Posidonia lateralis.



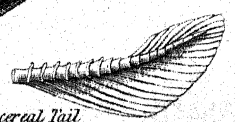
Avicula Damnoniensis.



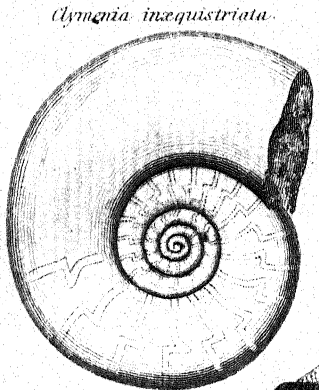
Homocercal or recent form.



Heterocercal Tail Palæozoic form.



Clymenia inæquistriata.



Pentremites inflatus.



Strigocephalus Burtini.

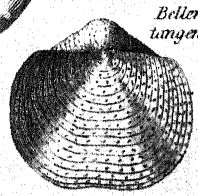


CARBONIFEROUS.

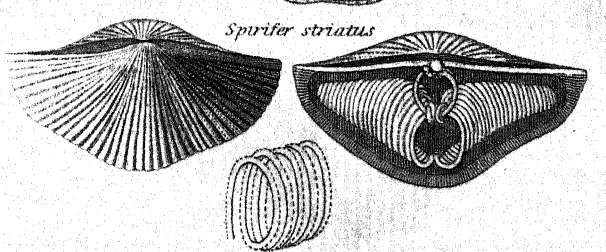
Bellerophon tangentialis

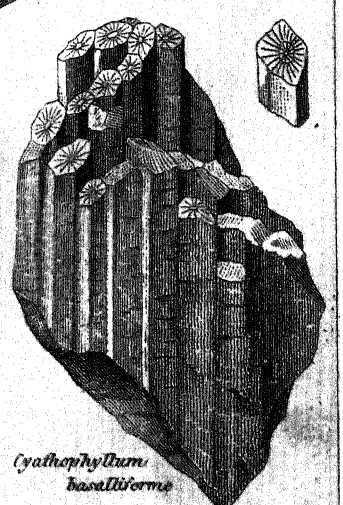


Productus fimbriatus



Spirifer striatus



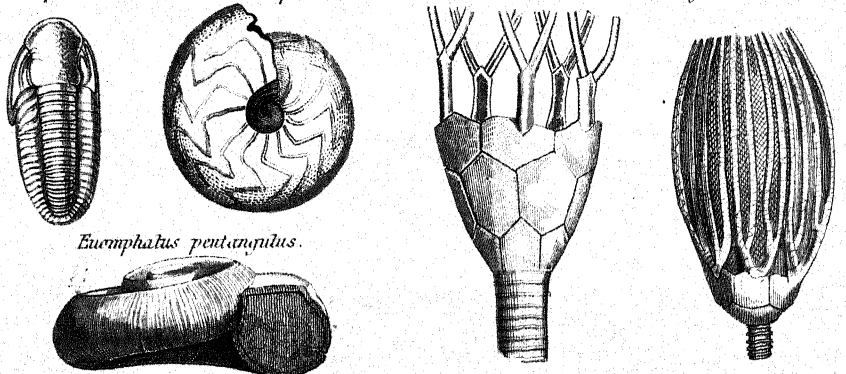


Cyathophyllum basaltiforme

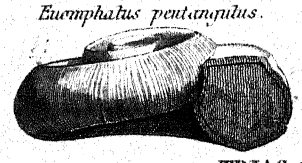
J.W. Lowry fc.

London, John Weale 59 High Holborn 1848.

Phillipsia Jonesii *Goniatites sphæricus.* *Poteriocrinites tenuis.* *Platycrinites lævis.*



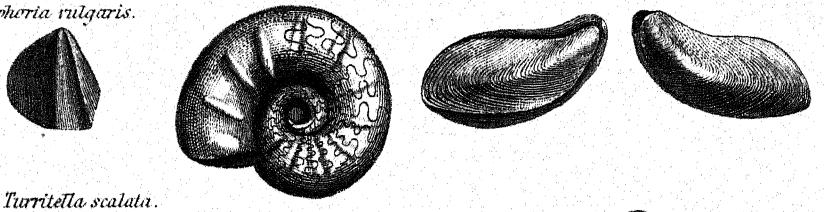
Euomphalus pentangulus.



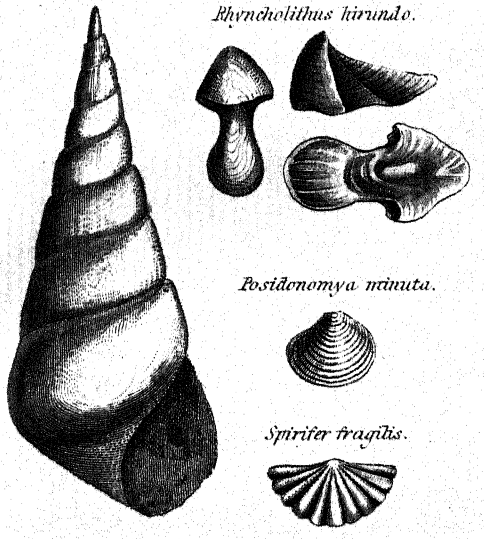
TRIAS *including* **MUSCHELKALK**

Ceratites nodosus. *Avicula socialis.*

Myophoria vulgaris.

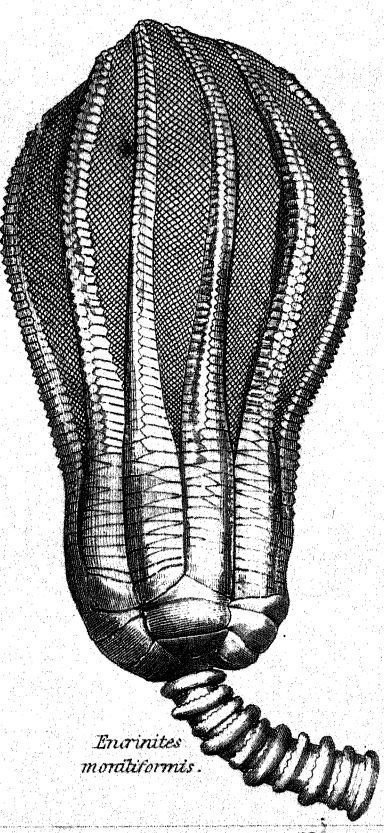


Turritella scalata. *Rhyncholithus hirundo.*



Posidonomya minuta.

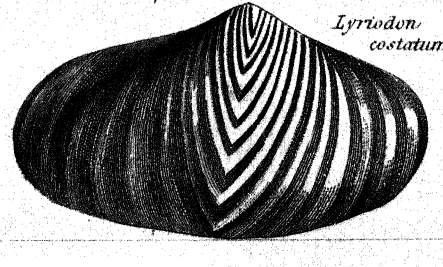
Spirifer fragilis.



Enarinites moniliformis.

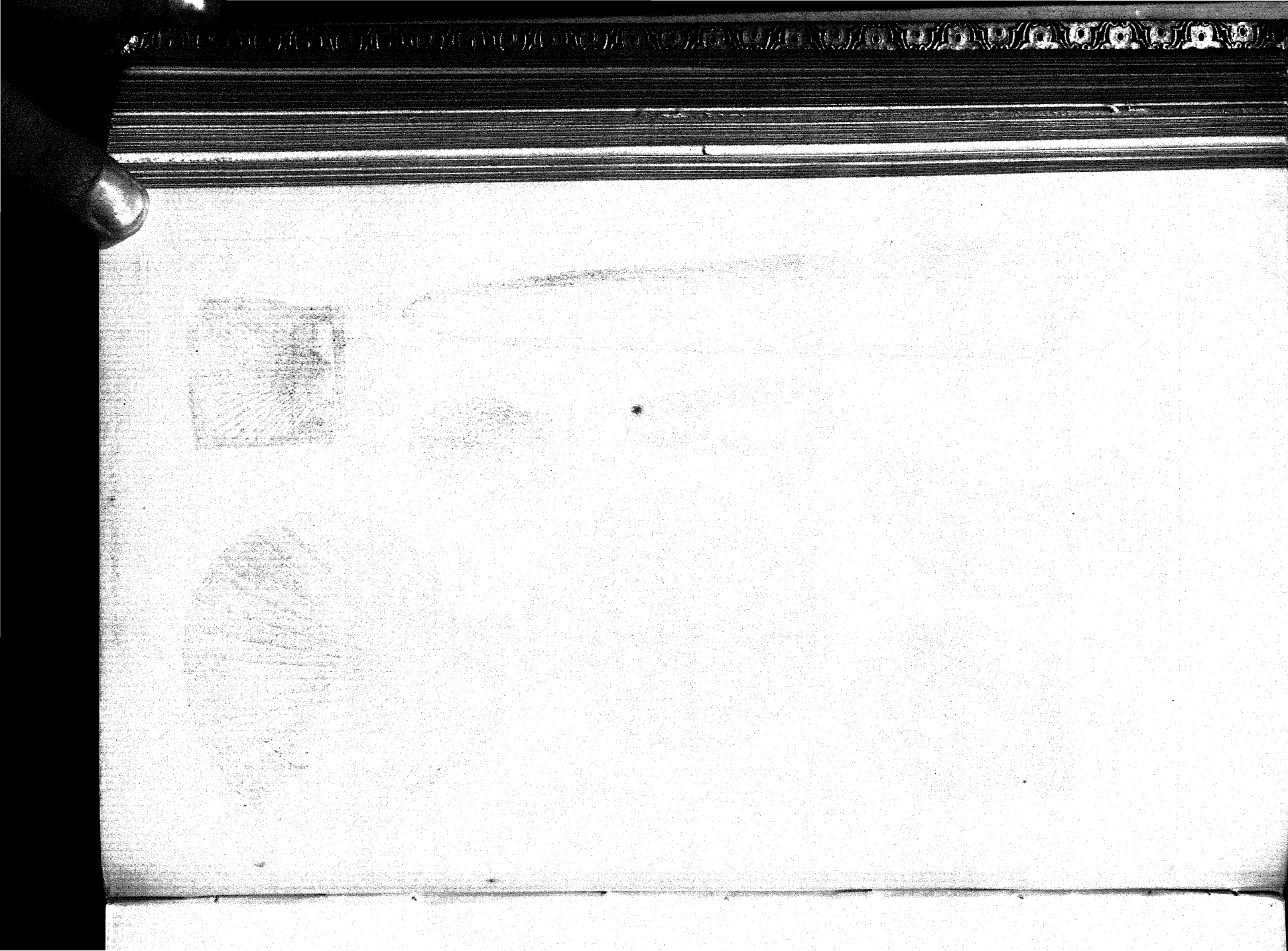
OOLITIC *including* **LIAS**

Lyriodon costatum.



J. W. Lowry fc.

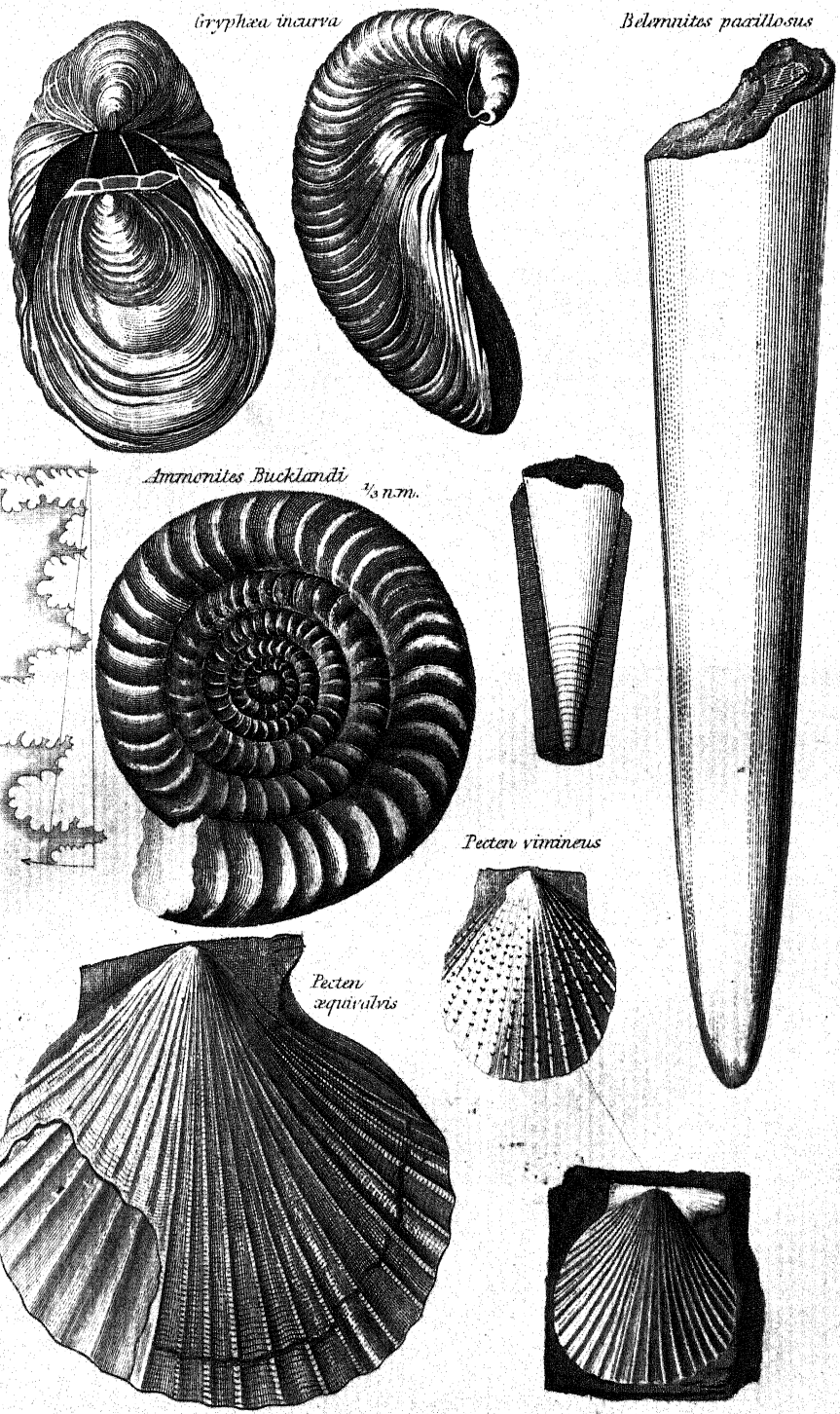
London, John Weale, 59, High Holborn. 1848.



JURA *or* OOLITE *including* LIAS.

Gryphæa incurva

Belemnites pacillosus



Ammonites Bucklandi 1/3 n.m.

Pecten vimineus

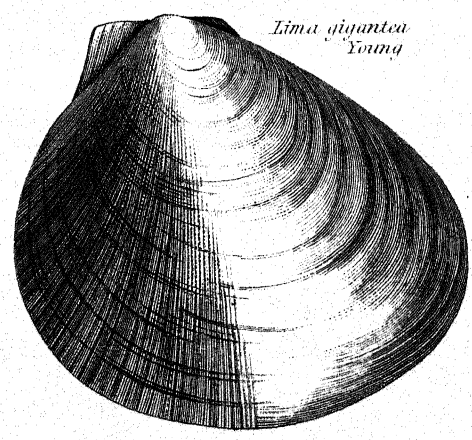
Pecten æquivalvis

J.W. Lowry fc.

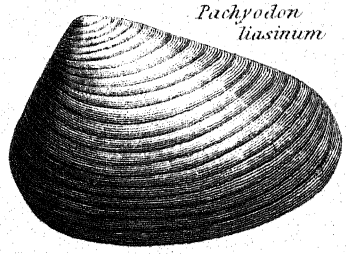
London, John Weale, 59 High Holborn. 1848.



JURA *or* OOLITE *including* LIAS.

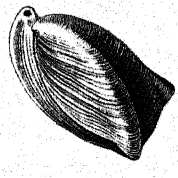


Lima gigantea
Young

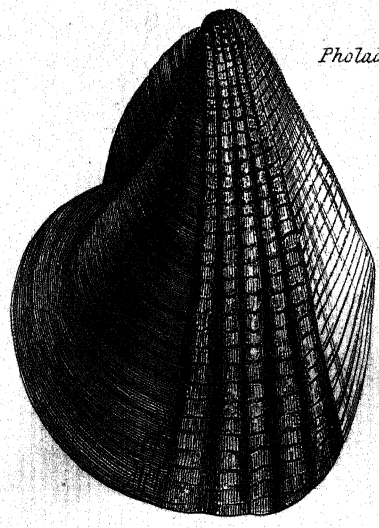


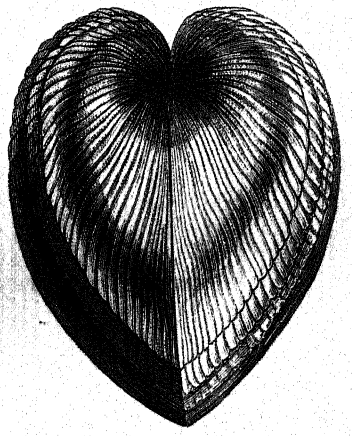
Pachyodon
liasinum

Terrebratula digona.

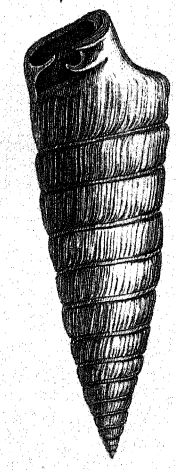


Pholadomya decorata.

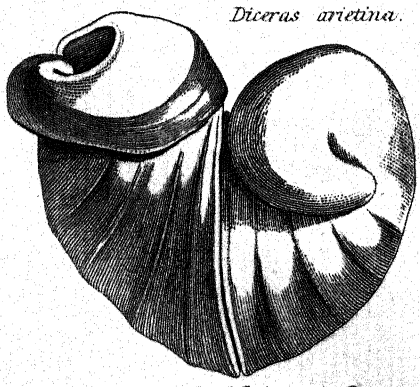


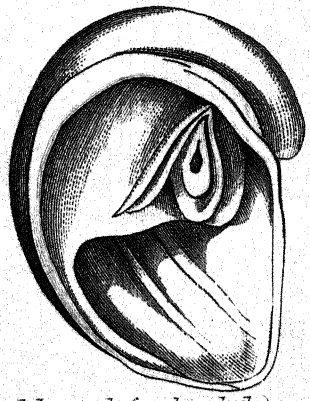


CRETACEOUS
Nerinea
equieniana



CRETACEOUS
Diceras arietina.





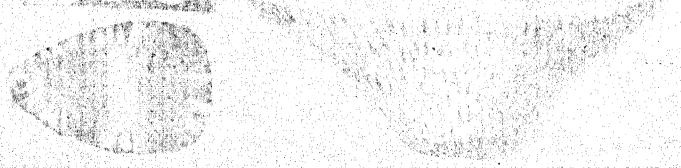


Section

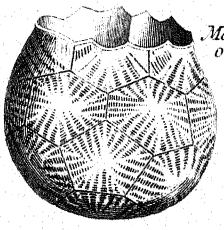
(differs from the Oolitic species by a rounded instead of a sharp keel.)

J.W. Lowry fc.

London, John Weale 59 High Holborn 1848.

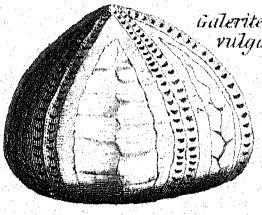


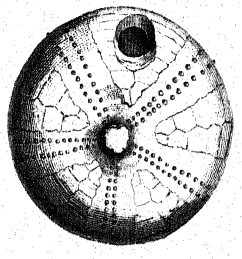
CRETACEOUS.



Marsupites ornatus

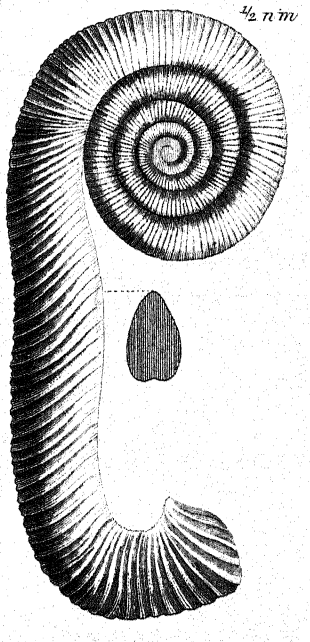
Galerites vulgaris





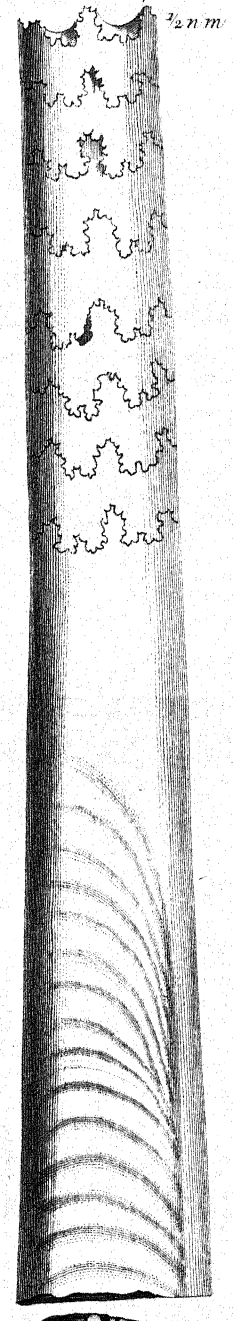
Saphites Yvanni

½ n m

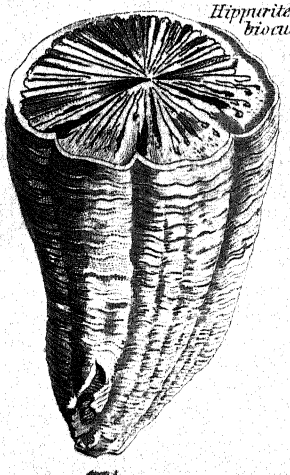


Baculites anceps

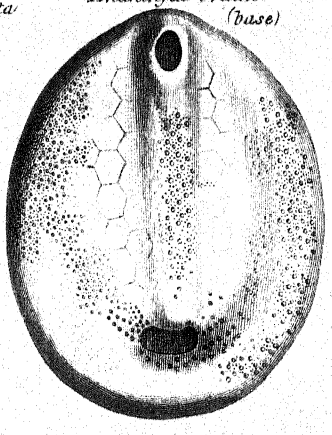
½ n m



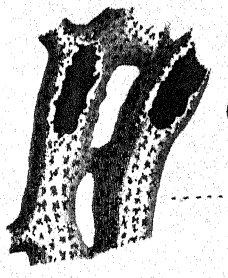
Hippurites bioculata

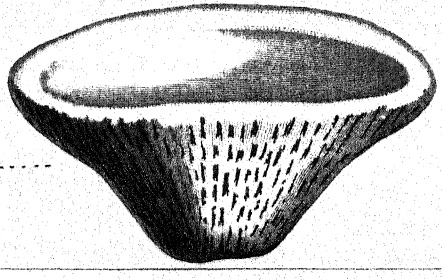


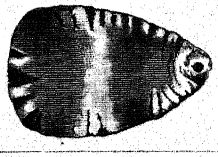
Ananchytes ovatus (base)



Ventriculites radiatus.

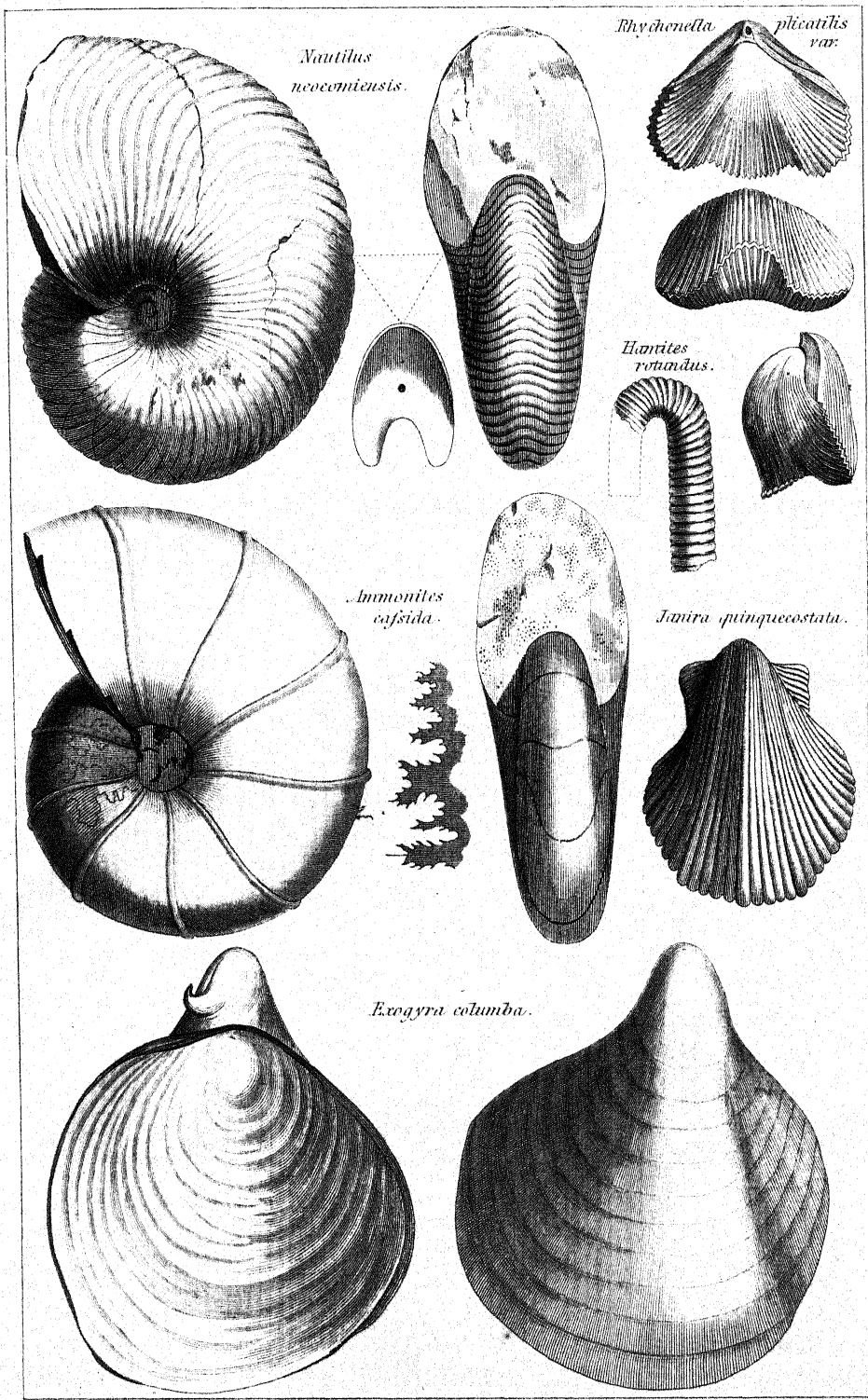






J.W. Lowry fc.

London. John Weale, 59 High Holborn. 1848.



The Tertiary Fofsils are reserved for the article "Palæontology"

J.W.Lowry fc.

London, John Weale, 59, High Holborn, 1848.

fractured bed or by some of the divisional clayey beds of such formations; and when once such bed or stratum has been discovered in any district, it becomes an index for the operations of the borer.

Although the several methods of boring cannot be here described in detail, it may be well briefly to notice the most remarkable.—1. The common one, in which an auger is used for soft soils, and chisels or jumpers for rocks. In this mode the boring tool is connected with the surface by jointed rods, fastened firmly together, and which must be frequently raised to clear the hole of the débris; so that in great depths the weight to be raised and the time lost in separating and refixing the joints become sources of great expense.—2. The Chinese mode, by percussion alone; the borer itself weighing about 180lbs., and, being suspended by a cord, is alternately raised and allowed to fall, the débris either passing up through grooves in the sides of the tool and being then drawn up when accumulated on the head, or received into a separate cylinder with a valve opening from below upwards. This method is much more economical than the common, and has been used very extensively in Germany, though it is subject to two accidents requiring great precaution,—viz. the great difficulty of drawing up a broken borer, and the danger, from the flexibility of the cord, of the bore-hole taking an oblique direction, and therefore requiring to be abandoned.—3. The system of Fauvelle, in which a hollow borer, whether it be an auger or a jumper, is used, the cutting tool being of larger diameter than the hollow stem, so that an annular space is formed around the borer; and water being forced down this space by a force-pump, ascends by the tube, bringing with it all the débris, or, if forced down the tube, ascends in a similar manner by the annulus. This arrangement renders it unnecessary to bring up to the surface the boring tools, as they are constantly kept clear, and a vast saving of time and expense is the result. (See Plate VII. for the tools of each system.)

Connected closely with the subject of boring is its application in the search for economic minerals, and enough has been said in the preceding pages to show the Engineer that there is a great difference in the positions of such substances, some being found like coal and salt and ironstone, arranged in distinctly stratified beds; and others, like many of the metals, in veins, each form requiring a modification in the mining arrangements, for the general character of which see the figures in Plates V., VI., and VII. Plates of some characteristic Fossils will be here given, so that every part of the Article may be available in practice; but a more complete view of the theory of the distribution of Fossils will be given under 'Palæontology,' which therefore see.

I may add that the *first satisfactory* determination of a quadrumanous fossil in the tertiary formation, was due to Lieutenants Baker and Durand, of the Bengal Army, in 1836.

In closing, therefore, this section of the Article 'Geognosy and Geology,' I trust I may be allowed to append to it a few words in a personal sense. The Editors of the work having desired not to omit the subject, requested me to undertake it; and I have done so in respondence to their anxious wishes to render the 'Aide-Mémoire' complete, though with a full sense of the difficulty of doing in so short a time full justice to it. I do not expect that my brother Officers will at present find the article perfect, but I do hope that they will be induced by its perusal to pursue a study so useful as Geology must be considered by all practical men; and if they do so, and are thereby led to examine the geological structure of the country and collect specimens at their various stations, I shall be happy to assist them in their researches during my continuance in England, by examining any specimens they may send home, and correcting, if necessary, their descriptions of them; and I would in this

respect particularly direct their attention to Fossils and to the material of superficial drift. In such matters as this there ought to be a feeling of co-operation amongst us, a desire to advance the character of our profession, rather than that of the individual; and I can conceive no case in which it can be better displayed than in geological research. When, indeed, I reflect on the manifest practical value of the science, I am surprised that its cultivation has not been more encouraged amongst us, and equally so that only a very small number have, notwithstanding this primary difficulty, studied it. I hope, however, this partial neglect of our science will pass away, and that ere long, at all our stations, there will be found observers amongst ourselves ready to elucidate the natural history and discover the economic value, as well as to describe the military capabilities, of the countries in which they serve. J. E. P.

GRENADE, FRENCH,*—is only now cast for the hand; and 12-pounder, 24-pounder, and 32-pounder Shells serve for the defence of ramparts.

The large interior space is 3 *pouces*, 6 *lignes*, 6 *points*, in diameter; and the small one, 3 *pouces*, 5 *lignes*, 6 *points*, French measure.

We must bear in mind that this grenade, whose dimensions are given in the Tables, is of rather a heavy calibre to be thrown with the hand, and that for this object it would be better to have them of only 3 inches, of the calibre of 4, weighing 2 lbs.

Grenades for ramparts weigh from 16 to 18lbs., and their calibre is very varied.

Table of Dimensions of Grenades.

	GREATEST.			LEAST.		
	pouces.	lignes.	points.	pouces.	lignes.	points.
Exterior diameter	3	6	6	3	5	6
Thickness, at the sides	0	4	3	0	3	9
Thickness, at the bottom	0	5	3	0	4	9
Diameter at the top of the fuzehole	0	8	9	0	8	3
Diameter at the bottom of do.	0	8	3	0	7	9
Height from the bottom to the fuzehole	3	1	6	3	0	6
Weight	3 lbs. 4 oz.			3 lbs. 2 oz.		

A hand-grenade 3 inches in diameter, weighing 2 lbs. 10 oz., can be thrown by a man to a distance from 28 to 34 yards (*de* 13 *à* 16 *toises*).

GLASS HAND-GRENADES.†

Glass hand-grenades are sometimes made use of with good effect; they are much more portable than those made of iron, and much less expensive.

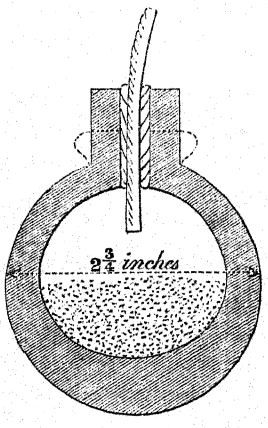
These grenades are used in Spain at present, and have been since the early part of the fifteenth century.

They are made of common green bottle-glass, of the dimensions shown in the accompanying diagram. They produce sharp flesh wounds, and though, like other grenades, more generally used in the *Defence of Posts*, may, from their portability, be easily carried by infantry in the attack of Entrenched Posts, particularly of stockades.

* From 'Aide-Mémoire d'Artillerie.' † By the late Lieut.-Colonel Alderson, R.E.

The accompanying diagram represents the grenade now in use in Spain, with the exception of the fuze, which is here shown as Bickford's slow-burning fuze, instead of the common tubes used in Spain, which are apt to go out in the neck of the grenade, and not explode.

Section of a Glass Hand-Grenade, loaded ready for use.



The projecting neck of this grenade may, I think, be shortened with advantage, as shown by the dotted line, as it is the part most liable to be broken, if it come in contact with a rock or wall when thrown from a height: the soldier should be instructed in those cases to roll it, whenever he can do so. A man can throw this grenade from 30 to 40 yards.

The weight of a glass hand-grenade is 10½ oz., or one-third that of an iron one, when loaded with one ounce of powder, or a common musket cartridge, and about 2 inches in length of the slow-burning Bickford's fuze fitted into the neck, as shown in the diagram; a little tow being wrapped round it if necessary, to make it tight.

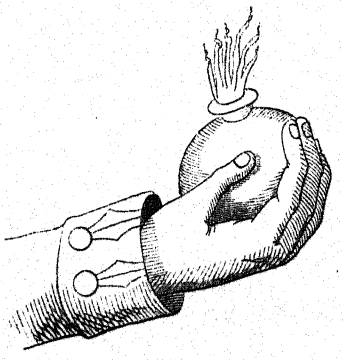
I have no doubt, on further trial, both with powder and gun-cotton, a much smaller space will be found sufficient for the charge, and that the glass may be proportionately increased in thickness, thereby giving larger splinters, and doing more damage.

In the manufacture of glass hand-grenades, the *greatest possible attention* must be paid to the *annealing process*, as unless this is *thoroughly* done, they will, on bursting, fly into thousands of minute particles, and become harmless.

METHOD OF LOADING AND OF THROWING GRENADES.*

The instruction is commenced by burning some fuzes between the finger and thumb, to show the party how long they burn, and that in the fuze itself there is no explosion, or danger.

The grenade is held as in the subjoined sketch.



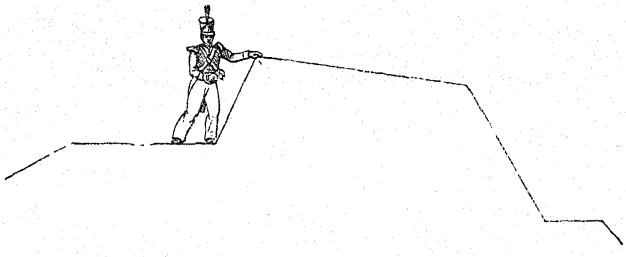
When it is lighted, the necessity must be explained of keeping the fuze turned towards the front, and a little downwards, until after the small explosion of the priming of the fuze, which is liable to burn and annoy the menwho may be next the grenadier.

The manner in which the grenade is held until after that small explosion, will be as represented in the woodcut on the next page; the port-fire burning immediately below it on the banquette.

After this has been fully explained to the party, they should be practised in throwing empty grenades, both from a work and into one, standing fast, and going through the motions of lighting the fuze each time a grenade is thrown. It is to be

* Chatham practice.

done with a pitching or swinging throw. After practising thus with empty grenades, a few should be thrown with fuzes; and after lighting them, they should be made to pause a little before they throw them, in order to teach them coolness. The party return again to practice with empty ones, continuing thus to throw empty grenades and grenades with lighted fuzes by turns, until they become expert in throwing them.



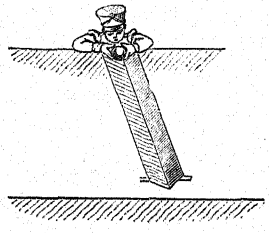
The following is the weight of loaded grenades and small shells:—

	lbs.	oz.
The Land Service hand-grenades weigh	1	13
The Sea Service grenade	4	2
The $4\frac{2}{5}$-inch shell	10	0
The $5\frac{1}{2}$-inch shell	16	0

The first is the best for the attack of works; but the $4\frac{2}{5}$-inch shell is the most convenient for the defence.

The $5\frac{1}{2}$ and $4\frac{2}{5}$-inch shells are thrown over hand, in the manner called 'putting.' Shells heavier than $5\frac{1}{2}$-inch cannot be thrown by the hand, and therefore they require a smooth surface, for the purpose of rolling them over the parapet.

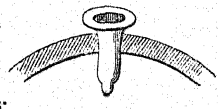
To form a run for heavy shells, take two planks and connect them together by a couple of smaller pieces of wood, in the same manner as is usual in making wooden gutters or spouts. The shell being placed in the trough, as in the annexed figure, may then easily be rolled over the parapet.



Grenades for Service are filled full of powder, but for exercise the following quantities are used, for blowing out the fuzes:

	Drachms.
Land Service grenades	6
Sea Service	9
$4\frac{2}{5}$-inch shell	$10\frac{1}{2}$
$5\frac{1}{2}$-inch shell	12

This small charge is put into a cartridge and fixed to the bottom of the fuze in driving it, thus.



Fuzes are made of the following materials:—

	lbs.	oz.
Saltpetre	3	4
Sulphur	1	0
Mealed powder	2	12

This proportion is to be well mixed with the hands, then run four times through a fine hair sieve, and mixed a second time.

The following Tables and Directions are chiefly extracted from the 'Pocket Gunner.'

Table for Driving Fuzes.

Nature of Fuze.	Weight of Composition.	Nature of Ladles.	Number of blows to each ladleful.	Number of threads of quick-match for each.	Number each man drives per diem.	Time each will burn.
inch.	oz. dr.	oz. dr.	number.	number.	number.	seconds.
13	2 8	2 0	21	4	9	35 to 38
10	1 8	1 0	18	4 or 3	9	33 35
8	1 0	0 8	15	3	12	29 31
$5\frac{1}{2}$	0 6	0 6	13	2	16	18 21
$4\frac{2}{5}$	0 6	0 4	12	2	16	15 17
Hand-Grenade	0 3		10		28	

Table showing the Dimensions of Fuzes.

Nature.	Diameter of the Fuze.			Diameter of the Composition.		
	Below the cup.	At the bottom.	At the cup.	Diameter.	Length.	Time it burns.
inches.	inches.	inches.	inches.	inches.	inches.	seconds.
13	2·1	1·575	2·49	·5	8·4	35
10	1·8	1·35	2·13	·438	7·2	33
8	1·3	1·25	1·78	·375	6·37	29
$5\frac{1}{2}$	1·1	·825	1·3	·275	4·4	18
$4\frac{2}{5}$	1·0	·75	1·18	·25	3·5	15
Grenades	0·8	·6	·9	·2	2·25	

Diameter inside the cup is 3 diameters of the bore.

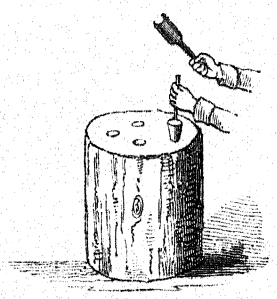
Depth of the cup, $1\frac{1}{2}$ diameter.

Thickness of wood at bottom of the bore, 2 diameters.

The articles necessary for driving fuzes are, large blocks of wood with holes at top, in which the fuzes are to be fixed, proper mallet, iron drifts tipped with brass, copper ladles of each nature, square boxes for holding the composition; in addition to which must be provided quick match and mealed powder.

In driving fuzes, the principal points to be attended to are,—to put in equal quantities of composition each time, which is effected by passing a round stick over the edges of the ladle,—to take off the composition along the edges, and to keep the strokes as steady and regular as possible, giving always the same number to each ladleful.

The drift is held in one hand, turning it round at each stroke, the fuze being kept steady in the holes by small wedges if necessary, as in the annexed figure, which represents the process of driving.

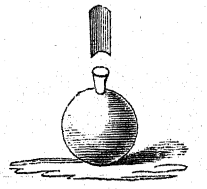


The fuzes must always be driven nearly to the height of the cup. They are afterwards primed with quick-match, and a ladleful of mealed powder put over it, which must be driven down with fifteen strokes of the mallet, and the cup filled up with mealed powder, moistened with spirits of wine, well pressed in with the finger.

The fuze is driven into the grenade by a few sharp blows of the mallet.



In fixing the fuze to the grenade, it is first pushed in by the hand; afterwards a round piece of wood having a conical hole at bottom is placed up the top of the fuze, to prevent the priming from being injured; and then the fuze is driven firmly into the shell-hole, by a few smart blows of the mallet upon the head of the driver, which is represented in section in the annexed figure.*



In two or three days, when the mealed powder is dry, fuzes intended to be kept in store for any length of time must have a circle of paper fitted to the top of the cup, and a cap of brown paper, or painted canvas, tied over all.

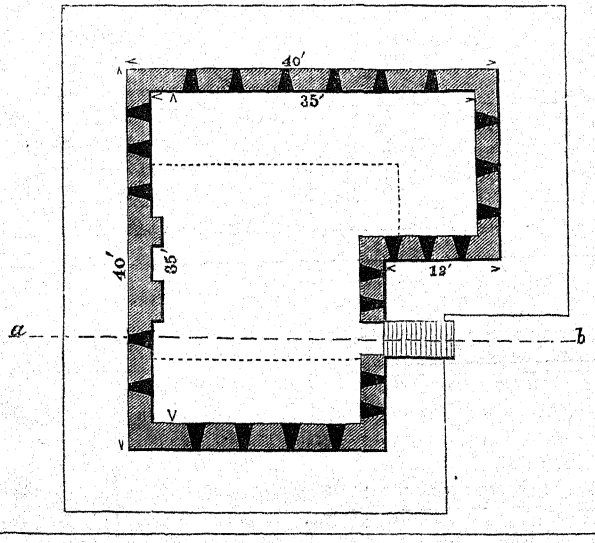
The following expedients may be used for defending ramparts in place of hand-grenades, viz. sound stone bottles, soldiers' wooden canteens, leather bags, canvas bags pitched over to prevent accidents, small tin cases, etc. By attaching a fuze to each of them, they may be thrown in the same manner as grenades.

GUARD-HOUSE, DEFENSIBLE.—Usually constructed of masonry, for the defence of *Flèches*, *Redoubts*, and *advanced works*, as likewise for the security of *Coast Batteries* and *Isolated Posts*.

Defensible Guard-Houses are not generally placed where a resistance is expected beyond a few hours, support being usually within a moderate distance; except in very peculiar sites, such as the gorge of a mountain inaccessible for artillery, or at the end of a causeway or morass, out of cannon-shot.

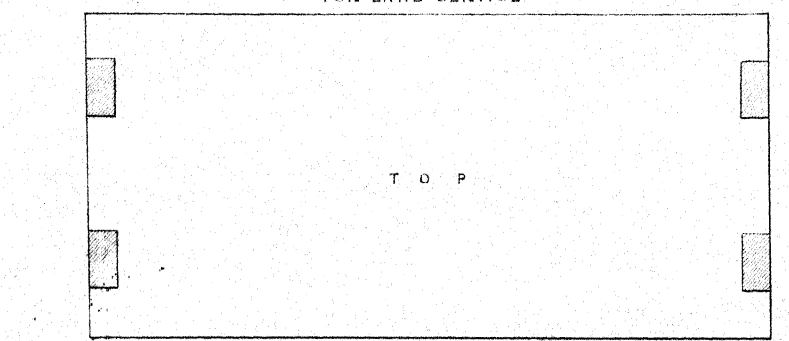
When constructed as an inner defence, defensible guard-houses should be well covered by the work: the building is intended to serve as a keep, and it should be incombustible, loopholed, and the entrance well secured.

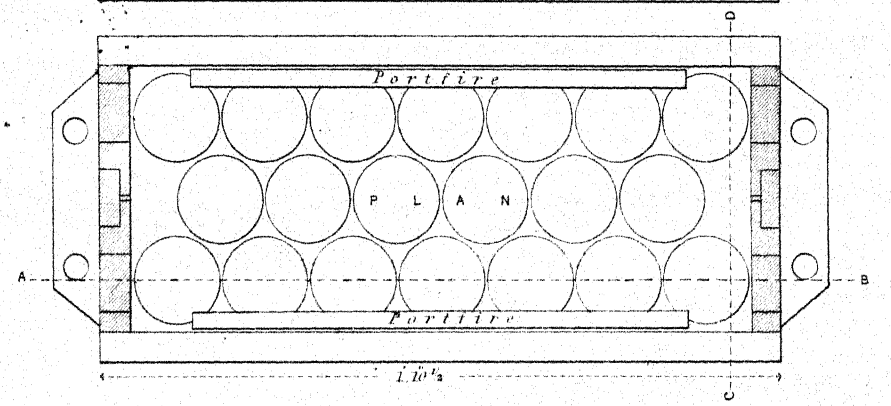
Fig. 1.



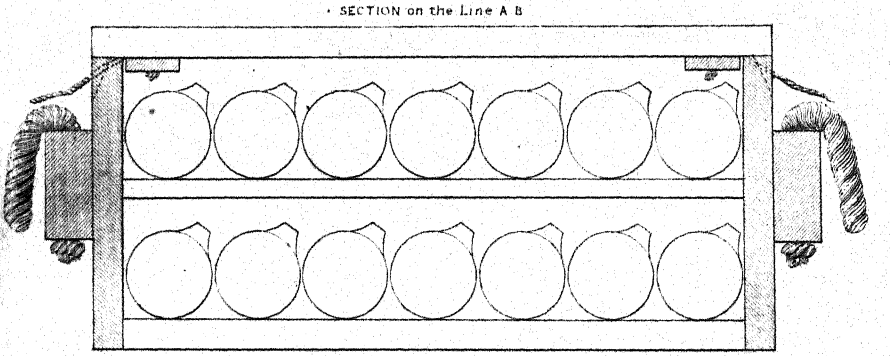
* Some tow is usually placed between the fuze and the driver, to prevent the fuze from splitting.

PLAN SECTIONS AND ELEVATION OF A BOX CONTAINING 40 HAND GRENADES FOR LAND SERVICE

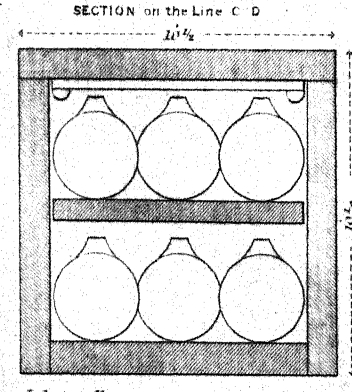




SECTION on the Line A B

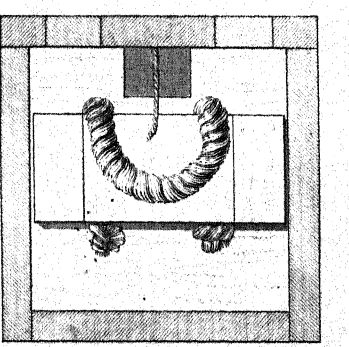


SECTION on the Line C D



Fuze to burn 8 Seconds
Weight of Box 91 lbs
The Box is packed
with Tow.

END ELEVATION

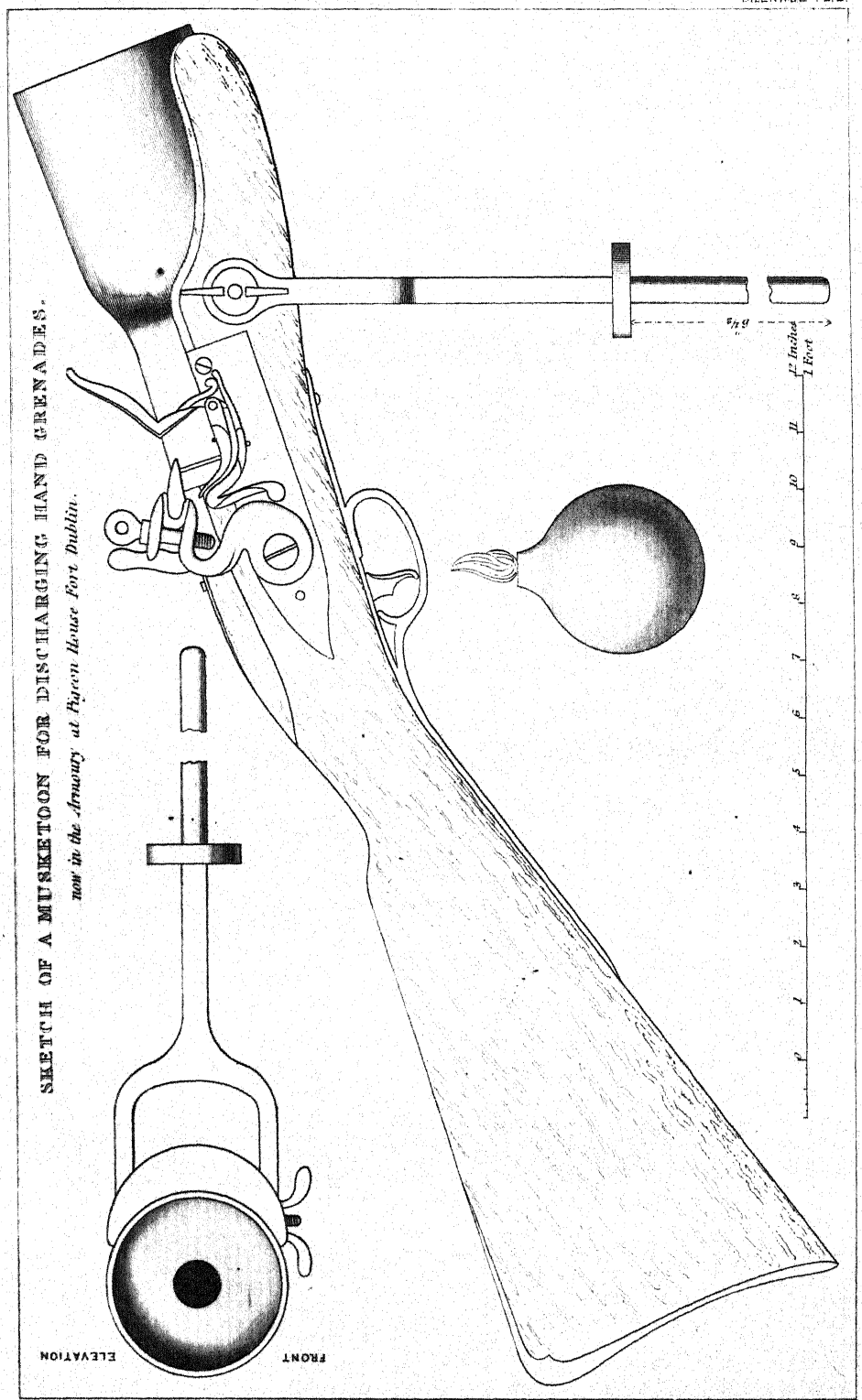




12 lb

J.W. Lowry fc.

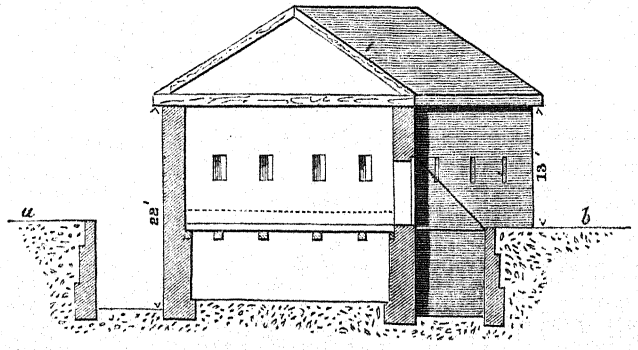
London, John Weale, High Holborn, 1848.



J.W.Lowry fe.

London. John Weale. 1848.

Fig. 2.



Figs. 1 and 2 are examples adapted to redoubts, flêches, and advanced field-works of a permanent nature; and if there is sufficient time, the entrance should be secured with a draw-bridge, well flanked by musketry fire.

Fig. 3.

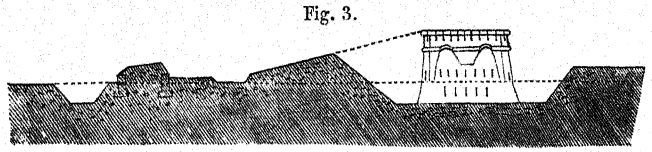
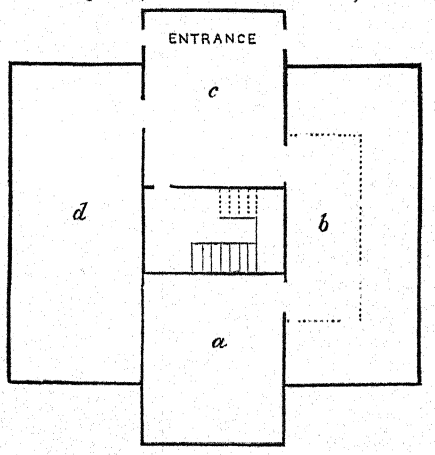


Fig. 4.



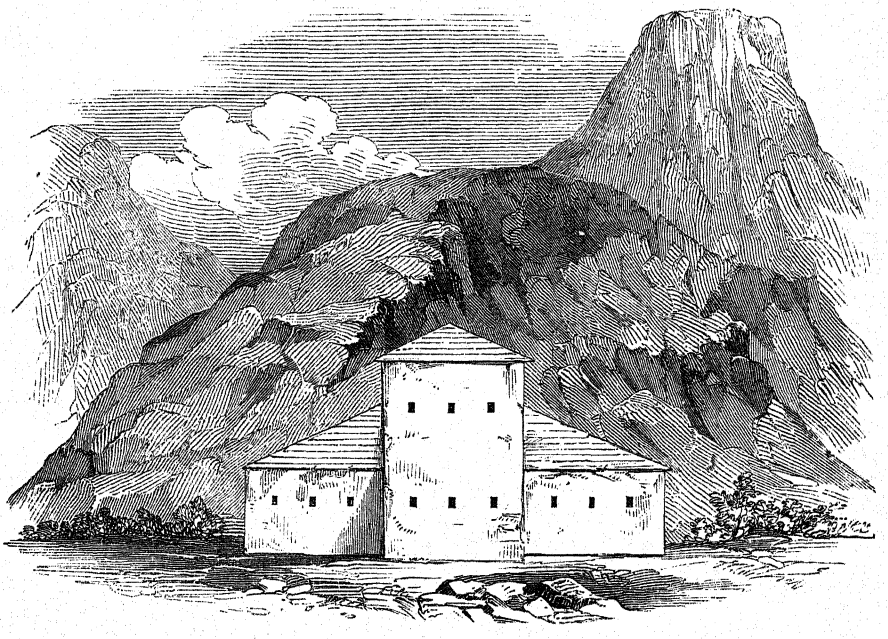
Fig. 5. (Scale, 20 feet to an inch.)



Figs. 3 and 4 are suited to coast batteries, taken from the French as a normal construction, for the protection of sea defences: for further detail see third volume of 'Professional Papers.'

Figs. 5 and 6 give the designs for a Cavalry Picket Guard-House in the mountains, where artillery cannot be brought against it; *a*, fig. 5, serving as the kitchen; *b*, men's room; *c*, lobby and guard-room; *d*, stables; over the kitchen is an officer's room, and over the lobby a store, as shown in fig. 6.

Fig. 6.



Figs. 7, 8, and 9 are Picket Towers, mounting a field-piece, placed on the frontier of the Cape of Good Hope, for the protection of the advanced posts.

Figs. 10 and 11 give a design of a Draw-Bridge adapted to the above works, when draw-bridges are required.

Fig. 7.—Barrack Floor.

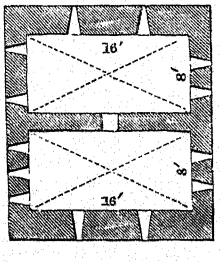


Fig. 8.

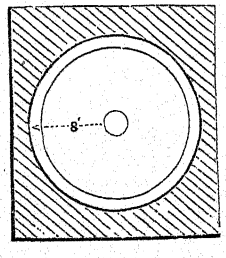


Fig. 9. (Scale, 20 feet to an inch.)

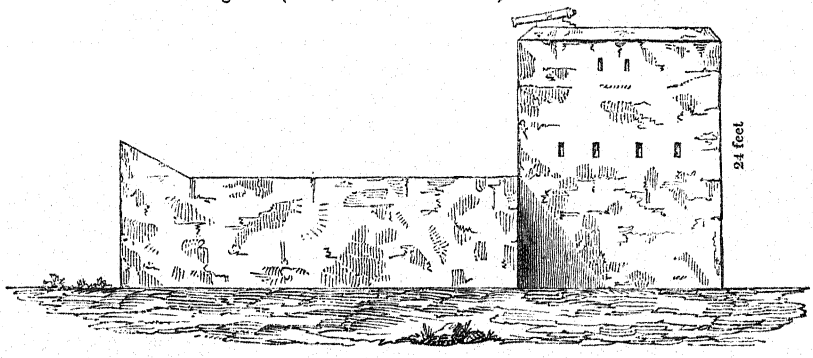


Fig. 10.

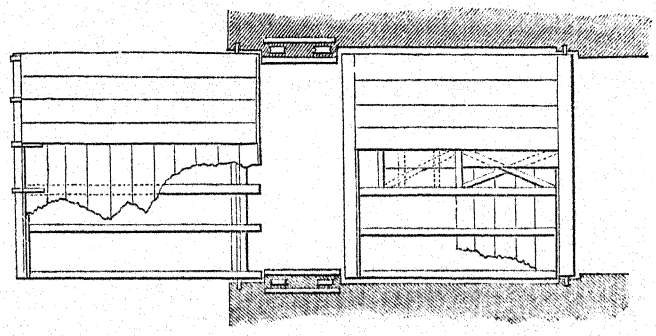
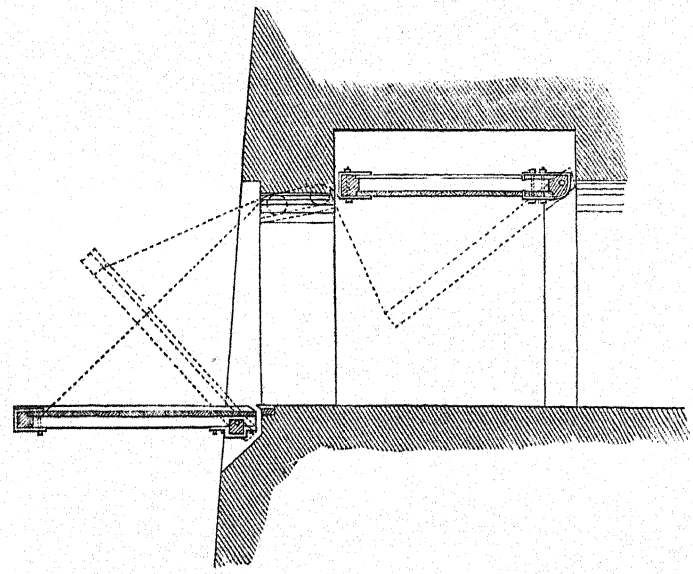


Fig. 11. (Scale, 8 feet to an inch.)



The principal advantages of this method are,—

1. That *theoretically* the counterpoise balances the platform in any position.

2. When the bridge is raised, the counterpoise acts as a gate. When the bridge is lowered, the counterpoise should be supported by a bolt; and when raised, the counterpoise should be secured in its vertical position.

The counterpoise is generally made rather lighter than the bridge; the axis of the latter is sometimes placed a little forward, that when the bridge is raised, it may rest against the escarp, without danger of falling down, if the chains should break; in which case, to lower the bridge, two men (or if a heavy one, four men) pass through the wicket in the counterpoise, and push down the platform of the bridge.

The platform is prolonged beyond the axis, to do away with the necessity of a movable board.

By using two rollers for the chain to pass over, the friction (vis inertiæ at first starting) is much diminished.

GUERITE,* (called also ECHAUGUETTE.)—This term was originally applied to the projecting stone or brick sentry-boxes or turrets, sometimes built at the top of the revetments of the salient angles of works in fortresses, the object of which is to enable sentinels placed in them to command thoroughly the ditches in front through loopholes, without being exposed to the enemy's musketry fire: they are, however, considered objectionable, from their marking the position of the salients, and facilitating the taking up the prolongations of the works by an assailant, for the purpose of enfilading their terrepleins.

In placing ordinary enclosures in a state of defence, similar buildings may often be constructed with advantage, to give a flank defence to lines of wall forming the boundary of a road or river where projecting works could not be built on the level of the ground for that purpose, or where, as in a dead re-entering angle, or over an entrance, a perpendicular or machicoulis fire is required.—(*See* MACHICOULIS.)

Figs. 1 and 2, of Plate 'Guerite,' show the mode of construction of a brick guerite built at an angle of the barrack enclosure at Drogheda, for the purpose of flanking the wall where it forms the boundary of a public road: having a roof, it affords good cover for a sentry, and enables him to watch through the loopholes the exterior of two lines of wall, without being seen by an enemy, and loopholes (*s*, *s*) in the floor give a machicoulis defence to the angle itself: it rests upon long stone corbels (*a*, *b*), the butts of which are secured by blocks of stone (*c*, *c*) placed across them.

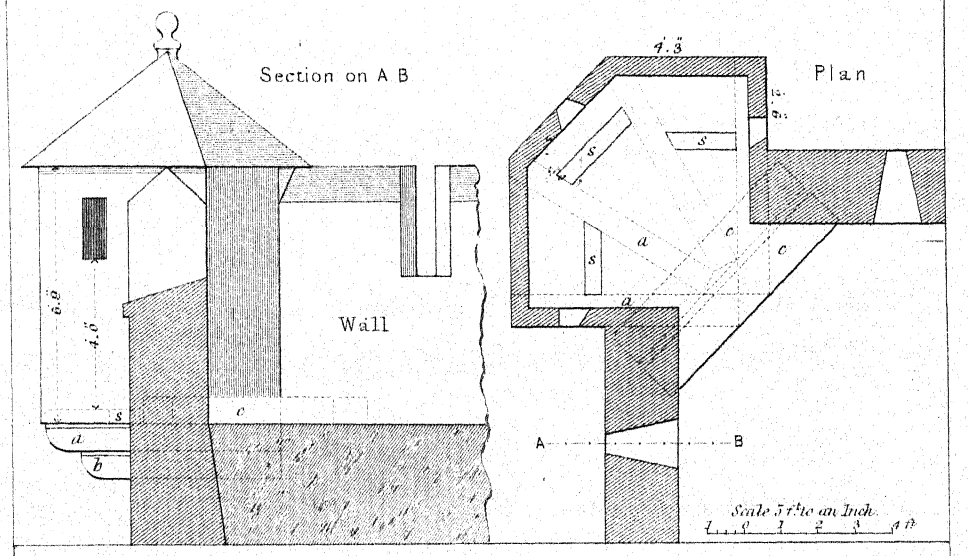
Wooden buildings of similar form have also been constructed at the angles of other barrack enclosures: these walls should of course be made thick enough to resist a bullet, or else must be covered with iron plates, and the corbels may be made of wood or iron.—(*Vide* BARRICADE.)

GUN COTTON.†—At the meeting of the British Association held at Southampton in the year 1846, it was announced that Professor Schönbein had discovered a mode of rendering cotton so explosive as to form an excellent substitute for gunpowder. Specimens of the prepared cotton were shown to the members of the Association by Professor Grove, who stated, however, that he was not at liberty to enter into any detailed account of that remarkable substance, as the inventor was about to take the necessary steps to secure protection by 'letters patent.'

As Professor Schönbein had previously announced that he had been able to obtain

* By Lieut.-Colonel Bainbrigge, R.E. † By Dr. Ryan, Royal Polytechnic Institution.

GUERITE

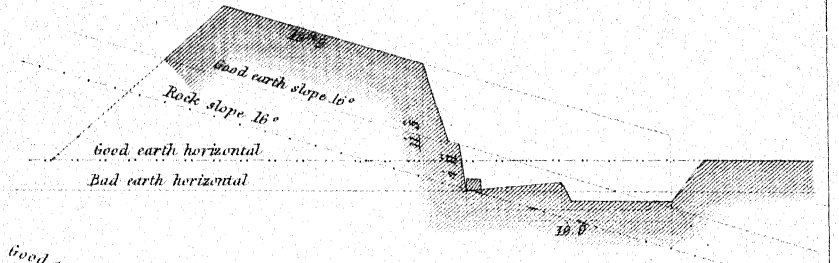


GENOUILLERE

(see platform)

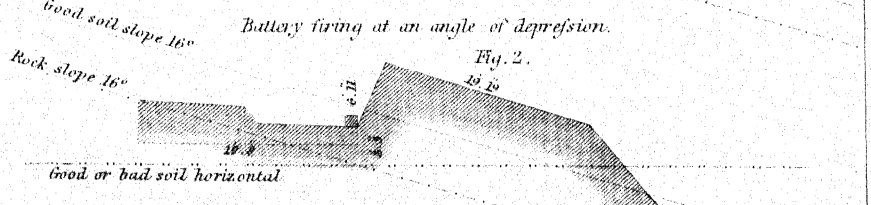
Battery firing at an angle of elevation.

Fig. 1.

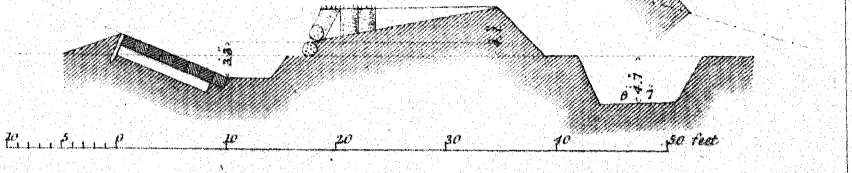


Battery firing at an angle of depression.

Fig. 2.



Mortar firing ricochet.



London. John Weale. High Holborn. 1848.

J. W. Lowry fc.

his newly described substance *ozone* in larger quantities, and as he had described it as most explosive, many chemists imagined that his fulminating cotton was impregnated with *ozone*. This, however, proved to be an erroneous conjecture.

Soon after the meeting at Southampton, Dr. Otto, Professor of Chemistry in Brunswick, published an account of an explosive cotton, discovered by himself, detailing at the same time his method of preparing it; and although it was found by those chemists who attempted to follow his directions, that his plan was neither very praeticable nor very successful, yet, by modifying his process, they were enabled eventually to prepare a cotton equal to Schönbein's, and thus to anticipate the specification of that philosopher's patent. Soon after Professor Otto's announcement, many other claimants started forward as the inventors of gun cotton: among these we may mention M. Morel, of Paris, and M. Böttger, of Frankfort. M. Morel obtained a patent in France for his invention, an account of which was laid before the Academy of Sciences by the celebrated Arago. It is only fair to state, however, that the general impression of the scientific world at the time was, that most of these persons were rather the successful *discoverers of Schönbein's secret* than the inventors of the substance they described.

The patent for preparing Schönbein's gun cotton was taken out in the name of John Taylor, of the Adelphi, Gentleman, under the title of a "Patent for Improvements in the Manufacture of Explosive Compounds." It is dated October 8th, 1846, and was enrolled April 8th, 1847. In the specification enrolled by Mr. Taylor, we have the following directions:—

"In preparing the cotton, the patentee makes use of nitric acid of sp. gr. from 1·45 to 1·50, and sulphuric acid of sp. gr. 1·85. These acids are to be mixed in the proportion of three parts of sulphuric acid and one part of nitric acid: the mixture is allowed to cool down to between 50° and 60° Fahr., and then rough cotton, previously freed from all extraneous matter, is immersed in the liquid, in as open a state as possible, in some suitable vessel of glazed earthenware. When thoroughly soaked, which process is facilitated by stirring with a glass rod, the excess of acid is to be drawn or poured off, and the cotton pressed lightly with an earthen presser, so as to separate the principal part of the acid. The cotton is afterwards covered over, and allowed to remain for one hour: it is then pressed, and thoroughly washed in running water, to divest it of all free acid, until it does not in the least degree affect litmus paper: it is then to be partially dried, by pressure; and to ensure its freedom from acid, it is to be washed in a dilute solution of carbonate of potash, made by dissolving one ounce of carbonate of potash in a gallon of water: it is then put under a press, and the excess of the alkaline solution pressed out, while at the same time the cotton is rendered nearly dry. In the next place, the substance is washed in a solution consisting of one ounce of pure nitrate of potash in one gallon of water; and when again pressed, is dried in a stove, or room, heated by steam, or hot water, to the temperature of from 150° to 170° Fahr. The nitrate of potash seems to increase the explosive force of the cotton; but it is not absolutely necessary. In using the cotton prepared as above, it must be borne in mind, that to produce the same effects much less must be used than of gunpowder; that is, in about the proportion of three parts of the prepared cotton* to eight parts of Tower-proof gunpowder.

* Gun cotton can be exploded by galvanic electricity, under precisely the same circumstances as gunpowder. The common electric spark will also ignite it, under the following arrangements. If an electric spark from a battery be allowed to fall upon a mass of gun cotton, it will produce *no effect*; but if the fluid be retarded in its progress, by being conducted over the surface of a piece of string, moistened with common water, and placed in contact with the cotton, an explosion takes place. —J. R.

"Explosive cotton may be prepared by using nitric acid only; but the patentee prefers using the above mixture of nitric and sulphuric acids.

"In using cotton prepared as above for the purposes of propulsion, as it is of a fibrous nature, it may be rammed at once into the gun; or, if made slightly moist, and then pressed into a mould, it will, when dry, retain its form, and thus may be made into cartridges.

"The patentee does not confine himself to the specific gravity of the acids above mentioned, nor to the exact process herein described; but what he claims is the converting vegetable matters into explosive substances, by means of nitric acid."—(*From the Patent Journal of April 17th*, 1847.)

Upon the publication of the specification, of which the foregoing is the substance, it was found that the chemists whose attention had been directed to the manufacture of gun cotton during the previous six months, had not only been able to make an article *resembling* Schönbein's, but in many instances had fallen upon his *precise* method. It is true that Professor Otto proposed the employment of *nitric acid* alone; but as we stated before, his method laid the foundation of the success of future manipulators. His directions were: "In the preparation of the exploding cotton, common well-cleaned cotton is dipped, for about half a minute, in highly concentrated nitric acid (the acid which I use being made by the distillation of ten parts of dried saltpetre and six of oil of vitriol;) and then instantly placed in water, which must often be renewed, in order to free the cotton from the acid with which it is impregnated. Care must be taken that all the knotty particles of the cotton are properly disentangled, and that it is thoroughly dried. After this, the explosive preparation is ready for use."

This plan of Professor Otto did not produce a very good cotton; besides, the difficulties and expense attendant upon the preparation of the acid were too great.

In the 'Times' newspaper of the 17th and 26th of October, 1846, appeared two letters from Mr. Thomas Taylor, of New Bridge Street, Blackfriars, in which he detailed a successful method of preparing the cotton, by the action of mixed nitric and sulphuric acids; acknowledging, at the same time, that his plan was merely a modification of Dr. Otto's. As the mode adopted by Mr. Taylor was a very simple one, and was very similar in its character to that employed by the Author of this Paper, as well as by other scientific men, we shall give it here as briefly as possible. "Mix in any convenient glass vessel, one ounce and a half, by measure, of nitric acid, (sp. gr. 1·45 to 1·50), with an equal quantity of sulphuric acid (sp. gr. 1·80). When the mixture has cooled, place 100 grs. of fine cotton wool in a Wedgwood mortar, pour the acid over it, and with a glass rod, imbue the cotton as quickly as possible with the acid. As soon as the cotton is completely saturated, pour off the acid, and with the aid of the pestle, quickly squeeze out as much of the acid as possible. Throw the mass into a basinful of water, and thoroughly wash it, either in successive portions of water, or underneath a tap, until the cotton has not the slightest acid taste. Finally, squeeze it in a linen cloth, and dry it in a water bath."

In making the explosive cotton, a much greater amount of fulminating power may be obtained by using a larger relative proportion of the acids to the cotton, or by using a stronger nitric acid. Nitric acid of the sp. gr. 1·50 answers much better than that of 1·45; it being a curious fact, that the cotton is much less acted upon by the strong acid. Thus nitric acid of sp. gr. 1·36 converts the cotton into a gelatinous mass.

It will be observed that the plan of Mr. Thomas Taylor is less tedious than that specified by Professor Schönbein's representative; and, at the same time, a cotton quite as powerful is produced.

Dr. Ryan noticed, at an early period, that some specimens of cotton gave off, during explosion, considerable quantities of nitrous acid vapours. As this did not uniformly occur, he imagined that it might arise from the presence of small quantities of nitric acid, owing to imperfect washing; he therefore proposed, that before drying, the cotton should be rinsed in water containing a small proportion of ammonia. This was found to be a great improvement: Professor Schönbein, to the same end, employs a solution of carbonate of potash.

To increase the explosive character of the cotton, Dr. Ryan also was in the habit of employing a weak solution of chlorate of potash, but he found that cotton thus prepared was extremely dangerous, from the facility with which it exploded by friction or percussion; he also noticed that it soiled and oxidated the gun-barrel very rapidly. Professor Schönbein employs nitrate of potash for the same purpose, and more successfully, as it does not soil or oxidate so readily the metal of the gun. Generally speaking however it is objectionable to employ any of the salts of potash, as they are liable to cause the production of smoke, or vapour, during explosion.

In the specification of Schönbein's patent, we are told that "the cotton in a damp state may be pressed into a mould, and afterwards made into cartridges." This however would never answer; for when the cotton is compressed, its explosion is often partial and uncertain. Thus, if a piece of cotton, four or five inches long, and half the thickness of the little finger, be laid on the table, and compressed in the centre by the edge of a card, or piece of sheet glass, one end may be ignited, and yet the explosion will not go beyond the compressed part. So, also, under the influence of percussion, or sudden compression, we have often merely a partial explosion, a great portion of the cotton remaining untouched. In fact, we never have the *full* force of the cotton exerted, except the mass be light, and uncompressed. Thus, in charging a pistol, for instance, a *pointed ramrod* is the best instrument to use.

Cotton, during its conversion into an explosive substance, increases very considerably in weight. Mr. Crum, F.R.S., in a Paper read before the Philosophical Society of Glasgow, on the 4th of November, 1846, gave an account of a number of carefully performed experiments, for the purpose of ascertaining the increase of weight. He says, that in order to guard against error, from different states of dryness, before and after the experiments, as well as from loss of weight in washing, it was accompanied through all the operations by another equal portion immersed in the same quantity of acid, to which had been added just as much water as would prevent the cotton from becoming explosive. The difference in weight between the two portions was assumed as the real increase.

Four different mixtures were used.—

I. Nitric acid of sp. gr. 1·5, with four-fifths of sulphuric acid, at 1·83.

II. Nitric acid of 1·48, with an equal volume of Nordhausen sulphuric acid of 1·86.

III. Nitric acid of 1·52, with an equal volume of Nordhausen sulphuric acid.

IV. Nitric acid of 1·43, with four-fifths of sulphuric acid of 1·83.

The increase upon 100 of cotton-wool was in each of them as follows:—

I.	II.	III.	IV.
70·0.	67·2.	66·2.	64·7.

The increase in weight, during the preparation, is owing to the conversion of a great portion of the cotton into a new and distinct chemical compound.

Cotton, in its unprepared state, is nothing but *lignine*, a compound of the three elements, *carbon*, *oxygen*, and *hydrogen*; but after the action of nitric acid, we find another element present, namely, *nitrogen*—a substance entering into the composition of nearly all our explosive bodies.

The influence of nitric acid upon vegetable matter has long been known to prac-

tical chemists. The Author has himself seen an old manuscript recipe book, where, among other things, it was remarked, that "tow or cotton should never be employed to stop bottles containing materials giving off nitrous acid fumes, as sometimes an explosion was the result." This recipe book was nearly a century old. But although these things were in some measure familiar to the chemist, it was not until the year 1833 that any philosophical investigation of the cause or nature of the action took place. In that year however, Braconnot, in a Paper published in the fifty-second volume of the 'Annales de Chimie et de Physique,' pp. 290–294, gave an account of a new substance, which he had obtained by the action of concentrated nitric acid on *starch*, *saw-dust*, *linen*, and *cotton wool*. To this new body, which he describes as being white, pulverulent, neutral, and very inflammable, he gave the name of 'Xyloïdine' (from ξύλον, wood). This compound is easily formed by boiling starch, for a few moments, in concentrated nitric acid, until solution takes place. On pouring the solution into cold water, the xyloïdine is precipitated, and may be collected and dried.

Five years afterwards, Pelouze, in the 'Comptes Rendus' for 1838, again drew the attention of chemists to this remarkable substance; and after describing xyloïdine, he refers to experiments of his own, which anticipate, in a great measure, Schönbein's discovery. "Xyloïdine," observes M. Pelouze, "is very combustible, taking fire at 180° Cent. (=356° Fahr.), and burning with great rapidity, and almost without residue.—This property has led me to an experiment which I think susceptible of some applications, especially in Artillery. By plunging paper in nitric acid of sp. gr. 1·5, leaving it there the requisite time for the acid to permeate the paper, which is usually accomplished in two or three minutes, then, withdrawing it, and, lastly, washing it in water, we obtain a kind of parchment, impermeable to moisture, and extremely combustible."

This substance was investigated by several eminent chemists, and among others by Dumas, who notices it in the sixth volume of his 'Traité de Chimie appliquée aux Arts,' p. 90, published in 1843. Dumas proposed to call the compound '*Nitramidine*.' He also mentions the application of paper and pasteboard, prepared by nitric acid, for fireworks (*pièces d'artifice*).

We have already stated, that by boiling starch in nitric acid, solution occurs, from which solution xyloïdine is precipitated by water; so also, if instead of starch we employ *cotton*, we have a similar result; for if we pour the solution of *cotton* in *nitric acid* into a vessel of water, a precipitate is formed, precisely similar in external appearance to that obtained from the starch. This led chemists, for a long period of time, to take it for granted that *xyloïdine* was the product in both cases. Schönbein was the first to point out the contrary. He shows that there is some slight difference between the two precipitates, as one is soluble in acetic acid, while the other is not. It would perhaps be well, then, for the future, to give to the starch-product the name proposed by Dumas, namely '*Nitramidine*,' indicating its probable composition; and to the precipitates from *cotton*, and other matters containing *lignine*, the term '*Xyloïdine*,' or '*Nitrolignine*.'

The explosive character, then, of gun cotton is owing to the formation of *xyloïdine*,* or *nitrolignine* (distinguished from *nitramidine*), in the tubes, and upon the exterior of the cotton fibre, under the action of the nitric acid. The sulphuric acid employed in the operation has no direct action upon the lignine; but is merely used to abstract the water of the nitric acid, and to render that substance more concentrated.

Gun cotton may be distinguished from common unprepared cotton, in the first

* *Pyroxyline.*—See Appendix C.

place, by its *harshness*, and by the *crepitating sound* produced when pressed by the hand. When well prepared, there is scarcely any perceptible change in colour or general appearance: some specimens are yellow, but that is the result of improper manipulation.

It may be distinguished from common cotton, also, in a moment, by its *electric condition*. This is a very important and satisfactory test. If a portion of the gun cotton be pulled briskly between the finger and thumb, taking care the hand is dry, the fibres of the cotton will adhere to the hand with great tenacity; and if a strip of prepared paper be thus treated, it will, if one end be presented to the knuckle, strike it many times in succession, giving off its electricity.

Gun cotton may be distinguished also from common cotton by its perfect solubility in sulphuric ether. If the ethereal solution be poured on the surface of cold water, the xyloïdine forms on the top of the water as an *opaque film*, resembling in texture and appearance the walls of a wasp's nest. This, when collected and dried, forms a very remarkable and explosive paper.

The fulminating cotton explodes with very great rapidity, and at a much lower temperature than gunpowder,—the point of ignition being about 350° Fahr., or, according to some, at 400° Fahr. If a small heap of gunpowder be placed on a sheet of writing-paper, and a little gun cotton be laid lightly upon it, and the whole held about a foot above the flame of a lamp, or candle, the heat will in a short time be sufficient to ignite the cotton, while the powder will remain unkindled; and although the cotton explodes while in contact with the powder, yet its action is so rapid that it exerts no influence upon that substance. This great rapidity of action is opposed to its utility for propulsive purposes. It is well known to practical men, that a slowly exploding material is the best for Artillery* practice. Thus, when a slow powder is used, the ball acquires a slight degree of motion, and puts the air in front of it in motion also, before the full power of the explosion is exerted; and that motion is gradually increased during the remainder of the explosion. But if the action takes place *too quickly*, the full force of the propelling power comes into play before the ball is in motion, and the bursting of the gun is the probable consequence. This is the reason why the fulminates of mercury and of silver have not been more extensively tried in warfare.

When gun cotton has been carefully prepared, the products of its combustion are *carbonic acid*, *carbonic oxide*, *watery vapour* or *steam*, and *free nitrogen*, with traces of nitric acid and of cyanogen. In some cases, as we before stated, nitrous acid is produced, owing to defective washing; and when nitrate of potash has been employed, or, in fact, a solution of any solid salts, a dense white vapour accompanies the explosion. The quantity of water produced during the decomposition of the cotton, by heat, is so great as to constitute an objection to its use in fire-arms.

Its hygrometric condition, also, impedes its utility; for if a quantity be exposed, for an hour or two, to a damp atmosphere, it absorbs nearly its own weight of water, and requires re-drying before it can be used: we have also stated before, that it cannot be protected from atmospheric moisture by compression into cartridges, as, in that state, it does not explode with certainty.

Dr. Ryan, at an early period of the discovery, pointed out that gun cotton might be so prepared as to give any coloured flame required; and in this way might be extremely useful for the construction of signal-lights, and also for the production of the usual pantomimic effects of our theatres. Thus, by using a solution of nitrate of strontia, before drying, the cotton would yield a red flame; with chloride of

* See Appendix A.

copper, a green flame;—and blue, with nitrate of baryta. Paper, linen, calico, etc., may also be prepared in the same way; and when any of these materials are rolled up tightly, they may be made to burn a considerable length of time, and produce a very pleasing effect.

The idea of employing the fulminating cotton as a substitute for gunpowder,* for Artillery purposes, seems to be completely abandoned; but, on account of the small quantity of smoke given off, as well as on account of its enormous force, it is used much for mining† purposes; the proportionate quantity used being a fourth of that of powder. In the 'Athenæum' of October 24th, 1846, we have an account of the employment of cotton for mining purposes, given at the meeting of the Royal Geographical Society, the week before, at Penzance, by Mr. R. Taylor. In that account he remarked, that where cotton was employed in the proportion of one-fourth of the usual quantity of powder, not only was the earth broken up satisfactorily, but the miners were able to approach the spot immediately, and resume their work; while, if gunpowder had been employed, as the mine was not well situated for ventilation, at least three-quarters of an hour must have elapsed, before the smoke would have allowed them to work.

In conclusion, we may state that an attempt has been made to employ gun cotton as a motive power instead of steam; but up to this period no well-authenticated cases of success have been published.‡—J. R.

APPENDIX A.§

Report of a Select Committee held at Woolwich, 3rd September, 1846.

Dr. Schönbein attended the Committee and delivered in a Paper detailing the proportions of his Explosive Cotton, and exhibited specimens of it in small quantities, prepared to different degrees of strength. He stated to the Committee, that he had verified the different properties which he ascribed to his preparation by many experiments, and proceeded to do so, in their presence, on a small scale. Some charges were introduced into a carbine, and exploded by the ordinary means of a percussion copper cap. They ignited readily, left the barrel perfectly clean, and appeared to have all the effects of gunpowder. A rifle loaded with the cotton, and the regulation belted ball, was discharged at a range of 80 yards, the effect and penetration of the ball being good.

From these trials, and from Dr. Schönbein's declaration, the Committee beg to report, that they consider the subject demands the fullest investigation, and they beg to recommend that Dr. Schönbein be applied to,‖ to furnish one hundredweight of his explosive cotton at the public expense, prepared in the strongest manner, which quantity would suffice to try the power and properties of the material on a moderate scale with muskets, rifles, and field-pieces. The Committee would report the result of the trials, with such recommendations as may arise out of them with regard to further experiments.

Properties of the Explosive Cotton, by C. F. Schönbein, Professor of Chemistry, 29th August, 1846.

1. It is more inflammable than gunpowder, but not yet ignited at a temperature of 400° Fahr.

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* See Appendix A. † See Appendix B. ‡ See Appendix C.

§ By permission of the Master-General and Board of Ordnance.

‖ This was never supplied.

2. It is not ignited by the friction or concussion occurring in charging cannon, mortars, rifles, or any other fire-arms, and mines.

3. Any of the means by which gunpowder is inflamed, also inflames the explosive cotton.

4. When prepared as strongly as possible, it does not produce any perceptible smoke or smell, nor leave any residue. A little less strongly prepared, it produces some smoke, but considerably less than gunpowder, and in this case the residue left is almost nothing; and fire-arms may be therefore discharged for any number of times without requiring cleaning.

5. The fire-arms are but little heated by using gun cotton, nor is their metal sensibly affected or corroded.

6. Water exerts no action upon strongly prepared gun cotton; for being dried again, it re-assumes all its primitive explosive force.

7. Gun cotton may be used in all cases where gunpowder is at present employed, without requiring any change in the fire-arms of the present construction.

8. From a great number of experiments made by Professor Schönbein, it appeared that in cannon and mortars, as well as in the rifles used in Switzerland, the propelling force of gun cotton is at least twice that of gunpowder, weight by weight. In America, with rifles of a certain construction (narrow bores and conical balls), the power of the explosive cotton is at least four times as great as that of the very best gunpowder. Similar results were obtained in blasting rocks and mines. With four ounces of explosive cotton, Professor Schönbein blasted, for instance, a very hard fragment of an old tower, of 250 cubic feet in size. To obtain the same result with gunpowder, at least two pounds of that article would have been made use of on the occasion.

9. The preparation of the explosive cotton does not expose to any danger of explosion, is most simple, and so quick that within 24 hours at most, the whole operation is gone through and finished. The arrangements for that preparation are equally of most simple description, and little expensive.

10. The materials required for making gun cotton are cheap, easy to be had, and there is every reason to admit that the same amount of propelling power produced by gun cotton will be sensibly cheaper than that obtained from gunpowder.

Note.—These statements have not been verified. The expense of gun cotton is considerably greater than gunpowder, and the application of the former for Artillery purposes has not been brought into use; and the quantity used in quarrying is limited. The subject of gun cotton and its component parts is not explained for the purpose of recommending its use, but by way of showing when it may be adopted under peculiar circumstances, such as the want of gunpowder, or the impracticability of conveying it to the spot. And yet gun cotton could be manufactured, if the materials are available, whilst the mining operations are in progress; or, if manufactured at a distance, the extreme lightness of the article renders it easy of conveyance in bags, in any quantity, or slung on a pole upon men's shoulders, and thus transported with safety where neither horses nor carriages could pass.—*Editors.*

DIRECTIONS FOR USING SCHÖNBEIN'S PATENT GUN COTTON, APPLICABLE FOR BLASTING EVERY DESCRIPTION OF ROCK AND MINERAL.

It is recommended that safety fuze should be used, and inserted into the cartridge to the extent of about two inches, and tied fast to the neck of the cartridge with a piece of string.

There is a black dot at one end of the cartridge, to show where the fuze is to be inserted.

The hole to be tamped should be made sufficiently large in diameter, that the cartridge may reach the bottom without there being any occasion to force the same down.

The hole should be made as dry as possible before the cartridge is inserted.

When the cartridge is down to the bottom of the hole, put into the hole a handful of dry sand or clay, so as to cover the top of the cartridge to the depth of one or two inches; then proceed to ram or stem down, precisely as in the case of blasting with gunpowder.

The fuze being cut off to the required length, according to circumstances, all is ready for firing.

Where there is an absolute necessity for using the gun cotton in a loose state, a wood rammer only is to be used.

Note.—It appears that gun cotton has been partially used in the quarries of North Wales, where 8 ounces of gun cotton raised 60 tons of slates in two consecutive trials, and at a great variety of places this explosive compound has shown its utility and enormous power. The patentees (Messrs. Hall and Co.) of Schönbein's gun cotton supply the article compressed in round and square paper cases of 4 oz. each, packed in boxes containing 50 and 100 cases.

It is considered by them that 4 oz. of gun cotton are equal to 24 oz. of blasting gunpowder.

Gun cotton is also made in tubes or

Cartridges of	1	1⅛	1¼	1½
containing	2	4	6	8 oz. each.

For blasting in quarries, paper tubes are made 3 feet in length, containing one ounce of patent gun cotton per foot.—*Editors.*

APPENDIX B.*

Results of comparative Experiments made with Pyroxyle, with Powder used for Small Arms and Artillery, with Powder as employed in Mines and the Extraction of Stones by blasting. Translated from the Report of the Commission to examine into the properties and powers of Pyroxyle as a projecting force.

1. In the spring of 1847, the above Commission, presided over by His Royal Highness the Duke de Montpensier, instituted at the Artillery Establishment at Vincennes two series of experiments on military mines, employing pyroxyle, mining powder, and the powder used in small arms and artillery.

2. Shortly afterwards the Commission caused a number of experiments on the extraction of stones by blasting, using the same explosive compounds under the direction of M. Combes. The pyroxyle used in these experiments has been analyzed by M. Pelouze. The experiments have led to the following results:—

3. Pyroxyle placed in a barrel, and pressed with the hand, has a density which is only one tenth that of powder; or more correctly, 0·084. In cartridges (dans les cartouches) this density can easily be doubled, that is, will be represented by 0·17, powder being unity. If, after being placed in the barrel, some mechanical force be employed to reduce its volume, its density may be increased fourfold; or

* By the late Lieutenant-Colonel J. Williams, R.E.

its value represented by 0·34. If the pressure be increased, the barrel breaks. With the last-named density (0·34) its explosive effects are as when pressed by the hand.

Composition of pyroxyle and powder; of their elements, and of the products of their combustion.

4. In order to facilitate the discussion of the relative powers of pyroxyle and powder (les propriétés des poudres et du pyroxyle), the atomical weight of the elements of each compound, as also of the products of their explosion (détonation),* are given in the annexed Table.

Comparative value of pyroxyle, powder used for small arms and artillery, and mining powder.

5. Let c represent the charge in gunpowder in a military mine, and c' a charge in pyroxyle: it has been found that when $c' = 0{\cdot}43\ c$, the radii of the craters produced by the explosions, and also the horizontal radii of rupture, are equal. Nevertheless, in the mine charged with pyroxyle, the solid of earth raised by the explosion was thrown upwards with less violence, and fell down again into the crater; and indeed it has been found, to produce with pyroxyle an equal lined crater as with powder, c' must be increased to $0{\cdot}60\ c$.

6. This anomaly may be explained by stating that the vapour of water, which forms $\frac{34}{92}$ of the products of the deflagration of pyroxyle, has at the moment of combustion a more expansive force than the permanent gases, but that when the vapour or steam comes in contact with the earth, it is soon entirely condensed, and ceases to act; but on the contrary, the products of the combustion of powder are permanent gases, not capable of condensation.†

7. The same anomaly is not remarked in the employment of pyroxyle in guns or small arms; because there is less surface in contact with the resulting gases, and the action is more instantaneous. In small arms, the coefficient of pyroxyle, to produce the same effect as gunpowder, is about 0·35. In the blasting of rocks, the required coefficient has been found to be 0·25 in relation to powder used for small arms and artillery, and 0·33 for mining powder; the strength of the former, compared with the latter, having been found to have the ratio of 0·33 to 0·25. The difference in expansive power in the two descriptions of powder may be explained by remarking, that the mining powder has less nitre, and therefore yields after combustion carbonic oxide and carbonic acid; and that the powder for small arms and artillery produces only carbonic acid. The carbonic oxide, as a gas, acts similarly in the explosion as carbonic acid, but having less heat, it has less elasticity.

8. The result of the above explanations points out that mining powder ought to be constituted similarly to powder for small arms and artillery; and that therefore nitrate of potash or nitrate of soda should be added, in order to supply the deficiency of oxygen. Experience has confirmed these suggestions of theory. By simply mixing 18 parts by weight of nitrate of soda, or 22 parts of nitrate of potash, to 100 parts of mining powder, M. Combes has made a gunpowder whose effects correspond exactly with the gunpowder employed for small arms and artillery.

New combustion of gases after an explosion of pyroxyle.

9. The products of the deflagration of pyroxyle contain carbonic oxide, and permit therefore of a new combustion of that oxide after the explosion. In experimenting with this view, M. Combes has succeeded in procuring this combustion; and this will explain the appearance of flame which is sometimes remarked after the explosion of mines charged with pyroxyle.

Amelioration of pyroxyle.

10. M. Combes concludes that it is always desirable to produce this second combustion after the ignition of the pyroxyle, by adding to the latter a compound that would supply it with oxygen. Experiments have confirmed M. Combes's opinions: it has been found that by adding to a kilogramme (2·206 lbs. English) of pyroxyle, 830

* I think "Détonation" here must be rendered Combustion, or perhaps Explosion.—J. W.

† Under ordinary pressure of the atmosphere.—*Editors.*

grammes (29·292 English ounces) of chlorate of potash, or 818 grammes (28·868 English ounces) of nitrate of potash, or 690 grammes (23·645 ounces) of nitrate of potash, effects have been obtained equal at least to that of an equal weight of pyroxyle. The dipping of the pyroxyle into a solution of nitre has been found to be injurious. The salt incrusts the cotton, and prevents the access of the fire to it.

Suffocation produced by pyroxyle, powder used in small arms & artillery, and mining powder.

11. From the investigations into the composition of confined air (de l'air confiné) by M. Felix Le Blanc—'Annales de Chimie et de Physique,' tom. v. p. 245, line 3,—it has been shown that a dog can live some time in an atmosphere composed of 70 parts of common air and 30 of carbonic acid; that in an atmosphere composed of 94 parts of air and 6 of carbonic acid, a candle will not burn; that persons in such an atmosphere breathe with difficulty, but run no danger from suffocation (d'asphyxie); that an air vitiated by the combustion of carbon, and containing

19·19	oxygen,
75·62	nitrogen,
4·61	carbonic acid,
·54	carbonic oxide,
0·04	carburetted hydrogen,
100·00,	

and where candles burn well, has been fatal to a dog and a bird. The carbonic acid enters in the above analysis only in the proportion of 4½ per cent.; the carburetted hydrogen is not a poison: of the other elements there is only the carbonic oxide which is so, and the above experiments show how small a proportion is necessary to produce suffocation.

12. From the analysis given in the Table, it appears that the gases produced by mining powder and pyroxle, containing a large quantity of carbonic oxide, must be considered as causing death by poison; and, under this view, the addition to this powder and to the pyroxyle of the nitrates, the presence of which corrects the carbonic oxide into carbonic acid, is strongly to be recommended, even if it did not augment the effects of the explosion.

13. But in considering suffocation as produced by the combustion of powder, there are other circumstances which it is important to inquire into.

In firing in a casemate, where the atmosphere soon becomes thick with smoke, and the sulphur and potash are observed on the dress of those present, there is much difficulty in breathing; yet under such circumstances there is no danger from suffocation. In the explosion, however, of a mine underground, where the gases evolved come in contact with the surface of the earth disturbed, it is often found that the miner, without any warning, dies from suffocation, while the candles still burn in the gallery.

Note.—I can, from personal experience, cite a very remarkable instance in illustration of the foregoing fact, which occurred in some extensive mining operations carried on at the Royal Engineer Establishment at Chatham, in 1844.—J. W.

Comparative Tables of the Chemical Composition of Powder and Pyroxyle are given on the following pages.

Table showing the Composition of Powder and Pyroxyle, together with the Products of their Combustion.

POWDER.						PRODUCTS OF COMBUSTION.*				
Nature of Powder.	Atomical Composition.	Atomical Formulæ.	Atomical Weight.	Relative Proportion by weight as deduced from		Nature of the Products.	Atomical Formulæ.	Atomical Weight.	Relative Proportion per cent.	Volume (Rel.) of the Gases.
				Theory.	As adopted in Practice.					
As used for small arms and artillery (de Guerre).	1 Nitre	$N O^5 K O$.	1264	75	75	Nitrogen	N.	175	10·36	2
	1 Sulphur	S.	200	11·85	12·5	Sulphuret of Potassium .	S K.	689	40·74	„
	3 Charcoal	3 C.	225	13·15	12·5	Carbonic Acid . . .	$3 C O^2$.	825	48·90	6
			1689	100	100			1689	100	8
Poudre de Mine, or blasting powder.	1 Nitre	$N O^5 K O$.	1264	64·40	62	Nitrogen	N.	175	8·9	2
	2 Sulphur	2 S.	400	20·35	20	Bisulphuret of Potassium	$S^2 K$.	889	45·2	„
	4 Charcoal	4 C.	300	15·25	18	Carbonic Oxide . . .	2 C O.	350	17·8	4
						Carbonic Acid . . .	$2 C O^2$.	550	28·1	4
			1964	100	100			1964	100	10
Pyroxyle.	2 Cotton	$2 (C^{12} H^{10} O^{10})$.	4050·0	57·2	„	23 Carbonic Oxide . .	23 C O.	4025	56·7	46
	5 Nitric Acid (concentrated) monohydrate . . .	$5 (N O^5 H O)$.	3937·5	55·5	„	1 Carbonic Acid . . .	$C O^2$.	275	3·78	2
			7987·5	112·7	„	5 Nitrogen	5 N.	875	12·72	10
	Deduct 8 Water . .	8 H O.	900·0	12·7	„	17 Vapour of Water .	17 H O.	1912·5	26·8	34
			7087·5	100				7087·5	100	92
Powder when made with Nitrate of Soda.	1 Nitrate of Soda . .	$N O^5 Na O$.	1062	71·4	„	Nitrogen	N.	175	11·75	2
	1 Sulphur	S.	200	13·45	„	Sulphuret of Sodium .	S Na.	487	32·80	„
	3 Charcoal	3 C.	225	15·15	„	Carbonic Acid . . .	$3 C O^2$	825	55·45	6
			1487	100	„			1487	100	8

* "*Détonation*" in original.—*J. W.*

Table showing the Composition of Powder and Pyroxyle, together with the Products of their Combustion—continued.

POWDER.						PRODUCTS OF COMBUSTION.				
Nature of Powder.	Atomical Composition.	Atomical Formulæ.	Atomical Weight.	Relative Proportion by weight, as deduced from		Nature of the Products.	Atomical Formulæ.	Atomical Weight.	Relative Proportion per cent.	Volume (Rel.) of the Gases.
				Theory.	As adopted in Practice.					
Mining* Powder with Nitrate of Potash added.	Mining Powder . . . Nitrate of Potash . . (See paragraph 8.)	$N O^5 K O + 2 S + 4 C.$ $\frac{2}{6} N O^5 K O.$	1964 422	100 21·5	,, ,,	Nitrogen . . . . . Sulphuret of Potassium . Bisulphuret of do. . . . Carbonic Acid	$\frac{2}{6}$ N. $\frac{4}{6}$ S K. $\frac{4}{6}$ S^2 K. 4 C O^2.	233 460 593 1100	11·9 23·4 30·2 56	$\frac{1}{6}$ 8
			2386	121·5				2386	121·5	
Idem.	Mining Powder . . . Nitrate of Soda . . .	$N O^5 K O + 2 S + 4 C.$ $\frac{2}{6} N O^5 Na O.$	1964 454	100 18·05	,,					
			2418	118·05						
Pyroxyle with Nitrate of Potash.	Pyroxyle . . . . . Nitrate of Potash . . (See paragraph 10.)	$C^{24} H^{17} C^{17} 5 N O^5.$ 4·6 $N O^5 K O.$	7087·5 5814·4	100 82	,, ,,	4·6 Carbonate of Potash 19·4 Carbonic Acid . . 9·6 Nitrogen . . . . 17 Vapour of Water . .	4·6 C O^2 K O. 19·4 C O^2. 9·6 N. 17 H O.	3974·6 5335·0 1680·0 1912·3	55·67 75·6 23·75 26·95	 38·8 19·2 34·0
			12901·9	182				12901·9	182	92
Do. with Nitrate of Soda.	Pyroxyle . . . . . Nitrate of Soda . . . (See paragraph 10.)	4·6 $N O^5 Na O.$	7087·5 4885·2	100·0 68·7	,, ,,	4·6 Carbonate of Soda . 19·4 Carbonic Acid . . 9·6 Nitrogen . . . . 17 Vapour of Water . .	4 C O^2 Na O. 19·4 C O^2. 9·6 N. 17 H O.	3045·2 5335·0 1680·0 1912·3	42·9 75·2 23·7 26·9	 38·8 19·2 34
			11972·7	168·7				11972·5	168·7	92

* In the original—"*Complément de la poudre de mine.*"

Table showing the Atomical Composition of the Substances which enter into the Fabrication of Powder and Pyroxyle.

Names.	Symbols.	Atomical Weight.	Rel. Volume of the Gases.	Names.	Symbols.	Atomical Weight.	Rel. Volume of the Gases.
Oxygen . . .	O.	100	1				
Nitrogen . .	N.	175	2	Cotton . . .	$C^{12}\ H^{10}\ O^{10}$.	900 1125 2025	
Nitric Acid . .	$N\ O^5$.	675	,,				
Hydrogen . .	H.	12·5	1				
Water . . .	H O.	112·5	2	Potassium . .	K.	489	
Nitric Acid monohydrate	$N\ O^5\ H\ O$.	785·5	,,	Sodium . . .	Na.	287	
				Potash . . .	K O.	589	
Carbon . . .	C.	75	,,	Soda	Na O.	387	
Carbonic Oxide	C O.	175	2	Nitrate of Potash	$N\ O^5\ K\ O$.	1264	
,, Acid .	$C\ O^2$.	275	2	,, of Soda	$N\ O^5\ Na\ O$.		
				Sulphur . . .	S.	200	

Remarks on the Use of the Comparative Tables of Composition of Powder and Pyroxyle.

There are two modes of considering the chemical constitution of gaseous bodies, namely, first, by the atomical weight of their combining equivalents; and second, by the number of combining volumes. In the Table, each of these views is exhibited; but in order to take practical advantage of the column of relative volumes, some caution is necessary to those who may not be in the habit of using chemical formulæ. The column of volumes corresponds to the column of atomical weight, not to that of relative proportion per cent., and expresses therefore by volumes what the other expresses by weight: thus, in the case of pyroxyle, 23 $CO = \overline{23 \times 175} = 4025$; but the combining volume of carbonic oxide is, as compared to that of oxygen, as 2 to 1, hence in volumes 23 $CO = \overline{23 \times 2} = 46$; 1 carbonic acid $CO^2 = 275$, but the combining volumes are 2, as in carbonic oxide; 5 nitrogen $= \overline{5 \times 175} = 875$, but the combining volumes are also 2, or $\overline{5 \times 2} = 10$: 17 vapour of water, or 17 H O $= 17 \times \overline{12{\cdot}5 + 100} = 1912{\cdot}5$, but in volumes, hydrogen and oxygen unite in equal quantities, so that the volumes are $17 \times \overline{1 + 1} = 34$.

If then the question arise, What is the comparative amount of volumes produced by the combustion of each description of explosive agent? the quantities given in the column of relative volumes must be reduced in the proportion of the gross atomical weight to the number 100, or to any other definite number representing the quantity used, and the Table thus reduced gives the following proportional quantities of gases produced by the combustion of an equal quantity of each material.

Poudre de guerre (for small arms and artillery) . . ·474 or 4·74
Poudre de mine (blasting powder) . . . . ·509 or 5·09
Pyroxyle . . . . . 1·299 or 12·99

It must be also kept in mind that in this Table the French system of considering oxygen as 100 and hydrogen 12·5 is adopted; whereas hydrogen is frequently considered 1 and oxygen 8, or water $1 + 8 = 9$; but knowing this difference, a mere inspection of any representation of a chemical formula in atomic weights where oxygen, hydrogen, or water occurs, must show which system has been adopted, and the corrections to be applied.

FIRST COMPARATIVE EXPERIMENT.

The following mines, charged with gun cotton, were exploded during the operations carried on at Bapaume during the autumn of 1847.

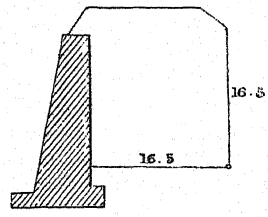
A charge of 29½ lbs. was placed behind the escarp of a ravelin, 4 feet 6 inches thick at top, and 9 feet 2 inches at bottom: the line of least resistance was 6·6 feet: the masonry was much shaken, but no practicable breach made, nor was the escarp thrown down.

In each instance of an experiment with gun cotton, a comparative mine was fired with gunpowder, with the view of ascertaining the relative force of the two compounds.

The equivalent experiment in powder to the above, consisted of a charge of 67 lbs., placed under similar conditions to the above. The explosion threw down the escarp, and formed a practicable breach, 25 yards wide. In assigning the ratio between gunpowder and gun cotton, so as to produce from the explosions an equivalent expansive force, the French Engineers had multiplied the charge of powder by decimal ·48: the result of the first experiment proved that this ratio was too high.

SECOND COMPARATIVE EXPERIMENT.

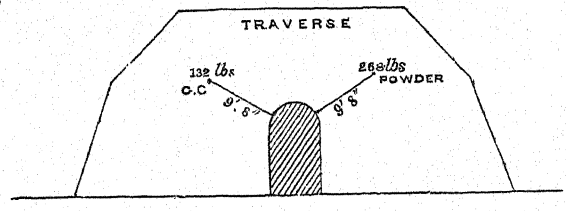
First, with Powder.—Charge 293 lbs.: L. L. R. 16·5 feet: distance also from chamber to front of escarp, 16·5 feet. The mine was placed the last-named distance behind the escarp of a ravelin, which it overthrew, forming a crater about 34 feet in diameter.



Same Experiment with Pyroxyle.—The factor ·48 having been shown by Experiment No. 1, to have been too small, it was increased to ·6: the charge therefore was 293 × ·6 = 175·8 lbs. The explosion showed the mine had been surcharged; not only by the more violent projection of fragments of the masonry, but by the form of the crater: the breach was quite practicable: the multiplier ·6 therefore gave a charge in excess.

THIRD COMPARATIVE EXPERIMENT.

First, with Powder.—Charge 268 lbs.: L. L. R. 9·8 feet: the latter in the direction of a gallery which it was the object of the mine to destroy. About 3 feet of gallery blown in.



Coefficient ·5.

The same Experiment with Gun Cotton.—The condition of the mine as above: the charge, however, was 132 lbs. The gallery was not injured from the explosion.

FOURTH COMPARATIVE EXPERIMENT.

Common mines situated under the terreplein of a ravelin.

First, Powder.—L. L. R. 13 feet: charge 205 lbs. The explosion produced a two-lined crater.

Coefficient ·5.

Second, Gun Cotton.—Charge 102 lbs. A similar crater was produced; the results of each explosion, as shown by the crater, being equal. Decimal ·5 appears therefore the proper coefficient.

A third experiment, under the above conditions of line of L. R., but adding 81 lbs. of nitrate of potash. No observable additional effect on the crater was produced by the addition.

Fourth Experiment. First, with Powder.—This experiment consisted of a disposition of three mines placed behind the escarp of a face of a bastion. The extreme mines were loaded with 668 lbs. of powder; the centre one with 400 lbs. The line of least resistance was 16·5 feet: the escarp 15 feet thick at bottom, and 7 feet 6 inches at top. The extreme mines were placed at intervals apart equal to twice the L. L. R. A perfect breach was formed, 30 yards wide.

Parallel Experiment with Gun Cotton.—The disposition consisted of three mines, each charged with 335 lbs. of pyroxyle: the L. L. R. was 18 feet; otherwise the other details were as above. Only one mine exploded: it produced a breach 20 yards wide. The cause of the failure of the explosion of the other mines was fairly attributable to some disarrangement having taken place in the hose.

FIFTH COMPARATIVE EXPERIMENT.

First, Powder.—A charge of 80 lbs. behind the escarp of a ravelin, with a L. L. R. of 8 feet: it was contained in a powder-box whose volume was ten times as great as that occupied by the powder. The result of the explosion shook the revetment, but did not throw it over.

With Pyroxyle.—Charge, 49 lbs.: circumstances of the mine as above, and the effects on the wall were about the same.

SIXTH EXPERIMENT.

Gun Cotton only.—Two charges of 400 lbs. each of gun cotton were exploded behind the escarp of a bastion, which was completely overthrown.

In addition to the above experiments, a small mine charged with gun cotton failed to ignite, probably from some disarrangement of the hose.

The gun cotton was placed in the chamber in bands, and fired by means of a hose invented by a Captain of Artillery, La Rivière, but very similar to our Bickford's fuze.

16th Oct. 1847. J. W.

From the results of the above experiments it appears, that when gun cotton is used in considerable quantities, only one half the equivalent weight of powder is necessary to produce the same result.

APPENDIX C.*

ADDITIONAL REMARKS ON THE HISTORY, COMPOSITION, AND UTILITY OF GUN COTTON.

The preceding Papers, which contain some of the latest practical experiments on gun cotton, leave a doubt on the mind as to its general utility; and it is desirable therefore to look further at the subject. As a substitute for gunpowder in the discharge of cannon, there is little chance that it should be ever rendered available; but that it may be so in the discharge of mines is extremely probable, and it ought to be considered an advantage to possess, especially in a large fortress, any additional

* By Colonel Portlock, R.E. and F.R.S.

means of defence. The mode of preparing gun cotton is very simple, and, with proper attention and definite rules, may be rendered certain and safe; so that at any time, in a well-provided Artillery Laboratory, it might on an emergency be prepared. The points to ascertain are, its real composition and the method of arriving at invariable results in its preparation. An uncertainty on this subject led chemists to confound the gun cotton of Schönbein with the xyloïdine of Braconnot; and Pelouse even, who claims to have suggested the preparation of combustible substances by the action of nitric acid on vegetable "cellulose" (as in cotton, paper, wood, etc.), so far back as 1838, confounded it with the xyloïdine of Braconnot, which was the pulverulent amorphous matter thrown down in precipitating by water a cold nitrous-solution of starch, or a similar hot solution of "cellulose." As M. Pelouze is correct in his statement, he certainly preceded Schönbein in this discovery; but it must be admitted that the discrimination of the substance, and its separation from xyloïdine, were the results of the discovery of Schönbein, and that he may justly be considered its real practical inventor, as he arrived at it by peculiar theoretic considerations on the nature of hydrated nitric and sulphuric acids, the existence of which compounds he doubts. In Schönbein's theory, a mixture of 2 equivalents of sulphuric acid and 1 equivalent of nitric acid should be represented not as $2\,(SO_3+HO) + NO_5+HO$, but as $2\ (SO_2+HO_2)+NO_4+HO_2$, and that the result of the mixture would be to set free 3 equivalents of a binoxide of hydrogen, $3\ HO_2$, which would act as a powerful oxidizing substance. Whether this theory be admitted or not, it shows a very distinct line of reasoning which is quite original to Schönbein. Schönbein commenced his experiments on sugar, which, in the state of fine powder, he formed into a very fluid paste with a mixture of 1 part nitric acid of 1·5 sp. gr. and 2 parts of sulphuric acid of 1·85 sp. gr. at 36° Fahr., which, being well stirred, emitted no gaseous exhalation. The viscous mass was then separated from the acid, well washed with boiling water until free from acid, and deprived, at a low temperature, of as much of the water as possible. Exposed to a low temperature, the substance was compact and brittle; at a moderate temperature, it could be moulded like jalap resin, and assumed a beautiful silky lustre: it was semi-fluid at 212°; at higher temperatures it gave off red vapours; and when heated more, it deflagrated violently without leaving a perceptible residue.* He then pursued his experiments on other organic substances, and made his principal discovery early in 1845 in respect to cotton, as well as in regard to those other substances described in the French Academy in Dec. 1845, and Jan. 1846. There can be little doubt, therefore, that but for this curious train of research, the former isolated discoveries of Pelouze and Braconnot would have remained without any practical result.

The latest English Paper on the subject, though several by Mr. Porrett and others had preceded it, is by Mr. John Hall Gladstone, of University College, London, and is published in the 'Philosophical Magazine,' Supplement, Dec. 1847. This writer first shows that well-carded cotton, perfectly white and free from impurities, is identical with lignine.

Cotton, as above analyzed by Mr. Gladstone.		Lignine, according to the Formula $C'_{24}\ H_{20}\ O_{20}$.	
Carbon . . .	44·37	Carbon . . .	44·44
Hydrogen . .	7·24	Hydrogen . .	6·17
Oxygen . . .	48·39	Oxygen . . .	49·39
	100·00		100·00

* Sobrero assigns to this body the formula $C_{12}\ H_9\ (N\ O_4)2\ O^{11}$, representing it as cane-sugar, in which 2 eqs. of peroxide of nitrogen have been substituted for 2 eqs. of hydrogen.

The excess of hydrogen in the first line is doubtless due to moisture absorbed in the operation.

The cotton was then steeped, until thoroughly wet, in a mixture of equal parts of nitric acid of sp. gr. 1·502, and strong sulphuric acid, then well washed with water, and dried at a temperature not exceeding 212°. In one instance 38·38 grs. became 66·84 grs., being an increase of 28·46 grs., or 74·15 per cent.: in a second, 59·3 grs. gave an increase of 43·7 grs., or 73·7 per cent. The gun cotton, or pyroxyline, thus produced, resembled the original cotton in physical properties very closely, and exploded at about 370°, producing no smoke and leaving no residue.

As the increase of weight in making gun cotton has been differently stated by various authors, Mr. Gladstone tried first the effect of difference of time of immersion, but found no alteration. He then tried the effect of different proportions of the acids employed. With 1 measure of nitric and 2 of sulphuric acid, he found in three separate experiments increases of 56·84, 59·93, and 70·6 per cent., and endeavouring to account for the discrepancy, he first immersed the cotton in a large quantity of acid, and obtained an increase of 73·1 per cent.; and secondly in a small quantity, so as merely to wet it thoroughly, when the increase was only 51·74 per cent., and the acid residuum gave evidence of the presence of organic matter, which, in the case of a large increase, such as 74 per cent., it did not. The substance obtained was in each case true pyroxyline, and the diminution in quantity Mr. Gladstone ascribes to a partial destruction of the cotton by the sulphuric acid, when the quantity of nitric acid present is small,—a result which induces a caution as to perfect immersion, also recommended from other reasons by the French.

Adopting Dr. Schönbein's specified method, or using 1 part of nitric acid of sp. gr. 1·5, and 3 parts of sulphuric acid, the increase was 75·20 per cent. in one experiment, and 75·47 in another; so that the method has the advantage as to quantity obtained, and is preferable, as sulphuric acid is more readily attainable than such highly concentrated nitric acid. The identity of the substances themselves obtained in each mode, was proved by analysis, and the true composition of pyroxyline ascertained to be—

Carbon .	26·23
Hydrogen .	2·73
Nitrogen .	12·75
Oxygen .	58·29

represented by the formula $C_{24}\left\{\begin{matrix}H_{15}\\5\,NO_4\end{matrix}\right\}O_{20}$.

Xyloïdine was next obtained by treating starch with fuming nitric acid until the whole was converted into a gelatinous mass, and then precipitating, by the addition of water, the xyloïdine as a white powder, which was well washed and dried. This xyloïdine exploded at 360°, leaving a carbonaceous residue. When analyzed, it gave a proportion nearly corresponding to the formula (though the nitrogen was in excess) $C_{24}\left\{\begin{matrix}H_{17}\\3\,NO_4\end{matrix}\right\}O_{20}$, in which the proportion of carbon to hydrogen would be 31·37 to 3·70, and not 26·23 to 2·73, as in pyroxyline; and it is this superfluity of carbon, which, as Schönbein observes, unfits it for an explosive agent. If nitric acid alone be used at sp. gr. 1·45, a substance different from pyroxyline is obtained, the formula of which is $C_{24}\left\{\begin{matrix}H_{17}\\3\,NO_4\end{matrix}\right\}O_{20}$, or that of xyloïdine obtained from starch; and this same substance may be obtained by the action of nitric acid of 1·45 on pyroxyline itself. And further, if this product of the action of nitric acid on pyroxyline be again submitted to the action of the mixed acids, pyroxyline is reproduced.

Pyroxyline.	*Xyloïdine.*
Insoluble in pure water; nearly insoluble in alcohol, ether, and mixture of ether and $\frac{1}{10}$ of alcohol.*	Insoluble in water; slightly soluble in ether; more so in alcohol; and still more in ether with a small quantity of alcohol.*
Acetic ether destroys its fibre, and dissolves it rapidly.*	Dissolves in acetic ether.*
Dissolved by strong sulphuric acid only when aided by heat.*	Dissolved by sulphuric acid without heat.*
Not acted upon by fuming nitric acid.*	Soluble in fuming nitric acid.*
Dissolves in hot solution of potash.*	Dissolves in a boiling solution of potash.*

Gun cotton, or pyroxyline, is also dissolved with long boiling, by ammonia, the alkaline carbonates, hydrochloric acid, and weak sulphuric acid.

The characters above exhibited show little difference between these two substances, and their close approximation is manifest from their respective formulæ; but it may be doubted, as stated by Mr. Gladstone, whether xyloïdine can always be considered a truly definite and fixed compound. Between that obtained from starch and that procured by Mr. Gladstone, from cotton, there is a difference in proportions, the starch xyloïdine giving carbon 24·0, nitrogen 3·42; and the cotton xyloïdine, carbon 24·0, nitrogen 2·65; but as both results approximate to the same chemical formula, they may be theoretically considered the same, or the "coton hypoazotique" of M. Payen; though Mr. Gladstone, from the circumstance of a different result in acting on starch xyloïdine and on his new substance respectively by the mixed acids, proposes to retain the distinctive appellation cotton xyloïdine. Starch, when treated by the mixed acids, yields a substance of greater combustibility than xyloïdine, and still more closely resembling pyroxyline, yet distinct from it in some physical qualities; and this substance is also produced by the action of the mixed acids on xyloïdine, so that there is the same convertibility between xyloïdine—and what may be called starch pyroxyline—as between cotton xyloïdine and the true pyroxyline.

This difference of results between the action of nitric acid combined with *more than one equivalent* of water, and that when it is in the state of a monohydrate, or combined with one equivalent only, in the one case giving rise to products corresponding to the formula of xyloïdine, and in the other to products resembling pyroxyline, deserves especial attention, as anything which tends in manipulation to place the nitric acid in the first state, or in combination with more than one atom of water, must lead to the formation of xyloïdine, and therefore be a failure: hence the use of even a much larger proportion of very weak sulphuric acid and a weak nitric acid will not be effectual in producing good gun cotton. To ensure success, it is desirable to have a nitric acid of about 1·5 density, and this, mixed with either 1, 2, or 3 parts of strong sulphuric acid, will form an effective mixture.

The next most interesting substance of this class is the gun paper of Pelouze, which is formed by the action of the mixed acids on paper, either in its manufactured state, or in the state of dried paper pulp. It has been much tried in France, the paper being either rolled into the form of a ball or cut into shreds. In composition it is identical with gun cotton, or true pyroxyline, and, in short, every form of pure lignine may be expected to yield a similar result.

M. Pelouze estimates the cost of 100 kilogrammes of gun cotton, including manufacture, at about 370 francs, and 100 kilogrammes of gun paper at 150 francs, or, in English weights and money, gun cotton £7. 8*s.* 6$\frac{3}{4}$*d.*, per cwt., gun paper £3 2*s.* 6*d.*

* These are results obtained by Mr. Gladstone.

per cwt.; but both from the early experiments by Mr. R. Taylor, in Cornwall, made in presence of Schönbein, and from those of the French, the relative strength of gun cotton to that of powder may be stated as 4 to 1; and by Pelouze's statement, that of gun paper to powder, 3 to 1: hence the relative cost for comparison would be thus:— quantity of gun cotton equivalent to 1 cwt. of powder . . . . } £1. 17*s*. 1½*d*. { Do. of gun paper } £1. 0*s*. 10*d*.

Both these substances, gun cotton and gun paper, have been tried successfully in fire-arms; but as the separation of the fibres of the former facilitates rapid combustion, it will probably be always found most suitable for that purpose; whilst in all those cases where it has been deemed desirable to condense the gun cotton, the gun paper made from paste or pulp will be found an equally advantageous and effective substance.

M. Pelouze has also tried to use his gun paper as a substitute for percussion caps; but though a loud detonation was heard, the matter was not perfectly consumed, and the fire was not regularly or with certainty communicated to the charge: but pyroxyline from any substance, used in a fibrous or shreddy condition, and placed in copper capsules, produced most powerful detonating caps; and gun cotton, mixed in capsules with a little common powder, was very effective.

The perfect combustion of pyroxyline is one of its most important qualities as regards fire-arms, but this is partially neutralized by the formation of much aqueous vapour. For mining it has this most important quality, that, after explosion, as in the case of the experiment made by Mr. Taylor at the Restomal iron-mine, the mine may be immediately entered, whereas it must be inaccessible for a long time after the explosion of gunpowder.

Without, therefore, exaggerating the advantages of this remarkable compound, it must be considered most important to be able, on an emergency, to convert all the ligneous substances available, by an easy and not expensive process, into powerfully explosive compounds. In endeavouring however to do this, let it be first kept in mind, that whether the action of sulphuric acid be merely to remove the superfluous equivalents of water from the nitric acid, or, according to Schönbein, to co-operate in liberating the peroxide of hydrogen, its presence is essential in at least an equal quantity to that of the nitric acid. 2ndly, That the cotton, paper, or other ligneous substance, should be fully immersed in the liquor, as the action of the air on the parts exposed may lead to the formation of an imperfect product. 3rdly, That great precaution is necessary in drying gun cotton, as the constant passage of air highly heated by contact with stoves, braziers, etc., may produce combustion, and, consequently, that no such stoves should be used in buildings where this material is prepared. The air heated by hot-water pipes (not on the high-pressure system) may be used with much safety.

In the field, the increase of bulk may counterbalance the diminution of weight; but it may be fairly suggested that in every great fortress provision should be made for rendering available, in time of need, the numerous substances containing lignine which are sure to be found in such circumstances.—J. E. P. Jan. 19th, 1848.

LATER OBSERVATIONS.*

Mr. Hadow has carefully investigated the action of mixtures of sulphuric and nitric acids upon cotton, and has pointed out the existence of several distinct compounds, the formation of which is regulated by the conditions under which the action takes place.

* By C. L. Bloxam, Esq., of King's College, London, and the R. M. Academy.

These experiments lead to the inference that the true rational formula of cotton is $C_{36}\,H_{30}\,O_{30}$. The production of the different compounds would then depend upon the oxidation of successive equivalents of hydrogen by the nitric acid, and its removal in the form of water, while the spaces which had been thus left vacant in the compound were filled up by the peroxide of nitrogen (NO_4) resulting from the deoxidation of the nitric acid (NO_5) by the removed hydrogen.

The change might be represented by the following general formula, in which the combined water of the hydrated nitric acid is, for the sake of simplicity, omitted:

$$\underbrace{C_{36}\,H_{30}\,O_{30}}_{\text{Cotton.}} + n\,NO_5 \quad = \quad \underbrace{C_{36}\,H_{30-n}\,(NO_4)n\,O_{30}}_{\text{Pyroxyline.}} + n\,HO.$$

The composition and properties of the pyroxyline depend therefore upon the value of n. It is necessary to bear in mind that n does not represent the amount of anhydrous nitric acid (NO_5) which is present in the mixture, but merely that portion which acts upon the cotton, and which appears to depend upon the proportion of water which the mixture contains. On considering the formula, it becomes evident that the action of hydrated nitric acid (HO,NO_5) alone upon the cotton must yield a very variable product, since the acid is continually diluted by fresh portions of water resulting from its action upon the cotton. Although, by employing a very large proportion of hydrated nitric acid, some approach to constancy might be made, it is far more convenient to employ hydrated sulphuric acid, which enters into combination with the liberated water, and virtually maintains the nitric acid of the same strength. The value of n may then be altered at will by altering the proportion of water which is added to the mixture of nitric and sulphuric acids.

Proceeding upon this principle, Mr. Hadow obtained the following compounds by acting upon cotton with mixtures of acids and water, of which the composition, expressed in equivalents, is annexed:—

A. $C_{36}\,H_{21}\,(NO_4)_9\,O_{30}$; produced by the action of any mixture not weaker than $HO,NO_5 + 2\,(HO,SO_3) + 3\,HO$.

B. $C_{36}\,H_{22}\,(NO_4)_8\,O_{30}$; produced by the action of $HO,NO_5 + 2\,(HO,SO_3) + 3\frac{1}{2}\,HO$.

C. $C_{36}\,H_{23}\,(NO_4)_7\,O_{30}$; produced by the action of $HO,NO_5 + 2\,(HO,SO_3) + 4\,HO$.

D. $C_{36}\,H_{24}\,(NO_4)_6\,O_{30}$; produced by the action of $HO,NO_5 + 2\,(HO,SO_3) + 5\,HO$.

The difference in the properties of these compounds is very marked, and of great importance in practice. *A* is the most explosive, the others decreasing in explosibility with the diminution of the peroxide of nitrogen. It is perfectly insoluble in a mixture of ether and alcohol, and therefore quite unfit for the preparation of Collodion for photographic purposes, for which the compound *B* is preferred to all others, being perfectly soluble. *C* differs from *B* in being perfectly soluble in acetic acid. *D*, though perfectly soluble, like the two preceding, in ether and alcohol, leaves an opaque instead of a transparent film when its solution is evaporated, in which respect it resembles the xyloïdine obtained by the action of nitric acid upon starch, with which it also agrees in composition. That it is not absolutely identical with that compound is shown however by the action of hydrosulphate of sulphite of potassium (KS,HS), which reconverts it into cotton, while xyloïdine would yield starch under this treatment. All the varieties of pyroxyline were found to be reconverted into cotton by the action of hydrosulphate of sulphite of potassium.

The acid containing 5 equivalents of *mixed* water was found partially to disintegrate the cotton, and when more water was added, the texture was completely destroyed.

The temperature at which the action of the acids takes place is not without influence upon the properties of the product, the increase of temperature having a tendency to

the formation of a compound containing less NO_4 than should be introduced into the cotton by an acid of the same strength at the ordinary temperature.

CONCLUSION.

Note on Gun Cotton by the Editors.—The perusal of the preceding pages on gun cotton will lead to the conclusion that there is no immediate prospect of its superseding gunpowder as an explosive compound, and it is possible other discoveries may render the application of gun cotton inexpedient.

The causes, as already explained, of the improbability of its being brought into general use, are—1. The difficulty of manufacturing gun cotton in large quantities, as the disaster at Faversham shows; 2, and hence the great expense (see Appendix A). Lastly, the danger, by friction, percussion, and even from moderate heat, under unaccountable circumstances.

These causes, after the novelty has worn out, will lead to the abandonment of gun cotton in quarrying, which, in fact, has already taken place, though perhaps in part from prejudices of the miners.

There is no question as to the power, and no secret in the manufacture of gun cotton, as explained in these Papers; but the adoption or application must rest in the judgment of the Engineer, in preference to or in the absence of gunpowder.

The discrepancy in the relative powers of gun cotton and gunpowder, as shown in Appendix B., and as stated by the manufacturers, Messrs. Hall, of Faversham, in Kent, in Appendix A., may, independent of the relative purities of the substances used, be accounted for by the different circumstances under which they were tried.

In England, almost our only practical knowledge of the compound has been derived in quarrying rocks; and as the gases are in such cases closely pent up, and have no means of escape, the effect is powerful, and the result should approximate to the French coefficient for small arms, viz. 0·35, or even to that for extracting stones, viz. 0·33, or 0·25 with the best powder. In the experiments the results of which are given in Appendix B., the gases mixed themselves with the soil, and the condensation of the vapour of water was facilitated, so that much of the moving force was annihilated; and this difference of result between blasting rocks and exploding a mine in earth had been also observed by Mr. R. Taylor in his early Cornish experiments. In earth mines therefore the charge of gun cotton must be one-half that of gunpowder, whilst in blasting or mining in rocks and old walls it may be reduced to one-quarter.

GUNNER,*—A term obviously derived from the word gun: one who is practically acquainted with the use of guns. In the improved state of modern artillery, to be master of the business of a gunner requires long and careful training and considerable experience. A gunner should be thoroughly acquainted with the powers and modes of serving the various descriptions of ordnance, whether guns, mortars, or howitzers, now in use, both for Field and Garrison Service. He must be acquainted with the nature of gunpowder, the mode of storing and moving it, and the precautions necessary in all operations where powder or other explosive and highly inflammable preparations are employed. He should be able to make up ammunition of all kinds, and to prepare all pyrotechnical, commonly called laboratory, stores: the nature of solid (round) shot, cold or hot, hollow shot, grape, case shot, spherical or

* By Colonel Wilford, Royal Artillery.

common shells, carcases, light-balls, and rockets, must be known to him, as well as the circumstances under which they are respectively best applied, whether his fire be direct, oblique, enfilading, vertical or ricochet, on land or water. He should readily appreciate distances over every variety of ground. The gunner must be conversant with the various modes of mounting and dismounting ordnance, and be familiar with the use of the engines, implements, etc., generally used in the Artillery Service. Although the British gunner, unlike Artillery of the military nations of the Continent, is not expected, as in the common course of his duty, to throw up batteries, lay platforms, etc., yet, as the exigencies of the Service may frequently call for the performance of such operations, where no adequate force of Sappers may be present, he ought to be instructed in those important branches of field-works. The French, Austrian, Prussian, and Russian gunner constructs his own battery, and then arms it; the British gunner should be capable of doing the same.

Enough has been said to show that, to form a really efficient gunner, an able-bodied, intelligent, and well-instructed man is required.

While the gunner can dispense with none of the ordinary qualities of a good soldier, he has special need of the greatest steadiness and coolness in action: the efficient service of his gun requires the combined efforts of several men; his duties are altogether more complicated than those of the Infantry or Cavalry soldier, and if he act from impulse, or in a hurry, he will nullify the services of others, and render his gun useless. The heavy guns and stores the gunner has to deal with, the variety of labours and fatigues incidental to his branch of the Service, make, as the French say, "le goût de travail;" that is, patience and goodwill in labour, most essential to him. The gunner is further required to be versed in the use of small arms, and is liable to be called on to perform all the ordinary duties of the Infantry soldier. Since the close of the Wars of the French Revolution, the designation of simply "gunner," has ceased to exist in the British Artillery, except in the small portion of the Corps styled the Horse Brigade, known as the Royal Horse Artillery. The men of the ten Battalions of Royal Artillery are now called "Gunners and Drivers," and every gunner is as essentially a driver as a gunner, and is called upon indifferently to perform the duties of a gunner or a driver, as may be required.

The duties of a driver, though not properly falling under the head of "Gunner," may be here glanced at.

The Artillery Driver must be able to drive all descriptions of horses and carriages, over every variety of ground. He must understand grooming, and the general care and treatment of his horse in all circumstances. In all field-battery drills and manœuvres much depends upon the intelligence and judgment of the driver, and, in action, he requires the highest degree of passive courage; he must sit quietly on his horse under the heaviest fire, ready to bring up his limber the instant ordered.

As the gunner and driver* has peculiar duties, so should he be imbued with a peculiar spirit proper to his vocation; and it were to be wished that his dress and equipments could have a more distinctive character, and be more in harmony with

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* Pay of the Royal Artillery in 1857:—

	s.	d.	
The pay of the Company Sergeant is	3	2	per diem.
Sergeant	2	8	,,
Corporal	2	2	,,
Bombardier	2	0	,,
Gunners and Drivers	1	3½	,,
Trumpeters	1	3¾	,,

The beer money is not included: one penny a day for all classes in Great Britain and Ireland.

It is in contemplation to give each Sergeant an additional sum of 2*d.* per diem in lieu of good conduct pay.—*Editors.*

his position as both a horse and foot soldier. The dress of the Artillery soldier should be soldier-like, but plain and useful, in keeping with the steady reflective character that ought to distinguish him.

Gunner, Garrison. A non-commissioned Officer of Artillery, usually a sergeant, is appointed, in garrisons abroad, to act under the Adjutant of Artillery in all matters relating to the receipt and issues of ordnance, ammunition and stores, between the Storekeeper, the Commanding Officer of Artillery, and Officers in charge of artillery districts; in making out demands on the Storekeeper, returns for the Commander of the Forces, the Adjutant-General and Director-General of Artillery, in preparing salutes, and other occasional duties. The Garrison Gunner has charge of the flags of the garrison, which he hoists on proper occasions, as directed by the Commanding Officer of Artillery.

Gunner, Master. The appointment of Master-Gunner is an ancient office under the Crown. In the time of Henry VIII., Master-Gunners, with a certain number of gunners under them, are found on the establishments of the various forts and castles erected for the defence of the country. Master-Gunners were sworn to keep faithful charge of the ordnance and stores in their custody, and duly to instruct in their craft the gunners under their orders. Since the establishment of a Regular Corps of Artillery, the situation of Master would appear to have declined in importance. It is now filled by pensioned sergeants of Artillery, appointed, on the recommendation of the Adjutant-General, by warrant from the Commander-in-Chief. Their duties are to take charge of and render half-yearly Returns of all ordnance, carriages, powder, shot, and other stores and implements of war, appropriated for the use and defence of their respective forts and castles.

They are required, with the approbation and written authority of the Governor or Commanding Officer on the spot, to take charge of any ammunition or stores on the production of regular bills of lading or delivery, reporting the circumstance, and sending the authority in every instance to the Head Quarters.

They are directed to salute on certain Triumph days, and to observe that 21 guns only, and those of the smallest nature, are to be fired: to acquaint the Governor or Officer commanding on the spot, and also the Officer of Artillery, before they fire on any occasion: to salute no person whatever without express orders from the Commander-in-Chief, or Adjutant-General of Artillery, except when Her Majesty or any of the Royal family are passing by. If the Governor or Officer in command on the spot, or the Officer* in command of the Artillery, should at any time require the Master-Gunner to expend any stores, or to salute on any occasion not provided for in the Instructions of the War Department, he is to request such order in writing, comply therewith, and represent the same.

He is to pay the greatest attention to the good order and preservation of the stores under his charge, that everything may be in a state for immediate service. He is to take charge of the Invalid Artillery Detachment at the station where he is Master-Gunner, and to consider himself in every respect under the orders of the Officer of Artillery commanding in the district, and at the fort, garrison, or post where he is stationed, furnishing to such Officer any Returns of ordnance and stores under his charge as he, the Officer, may require. Master-Gunners are amenable to military law, and subject to be tried by courts-martial.

Gunner, Quarter. This designation is usually applied to gunners of the Invalid Artillery, who are detached singly to different forts and castles, to assist and be specially under the orders of the Master-Gunners.

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* The Master-Gunner is likewise under the orders of the Officer of Artillery commanding the district, fort, garrison, or post.

GUNNER, NAVAL.*

To qualify an individual to receive a gunner's warrant, he must have been at sea at least seven years, one complete year of which as Gunner's mate, or other *petty Officer* or seaman-gunner in Her Majesty's Navy; and he must produce certificates of his servitude and good conduct; and pass such *examination* as the Admiralty may from time to time direct: but no *candidate* shall be examined before he shall have attained the age of 21 years, nor after the age of 35.

The Examination of Naval Gunner† to prove his being in all respects a good practical seaman; that he knows the use and service of the *great guns;* that he knows the proportion of powder for guns of every description, filling cartridges, and the arrangement in the magazine, *shells* and *fuzes*, and how to fill musket cartridges; that he can write sufficiently well, and understands the use of figures.

*Relative rank and Command of a Gunner** in Her Majesty's Navy is first on the list of Warrant Officers, and next to that of Officer, and follows that of Master's Mate in assuming the command of a ship.

Gunner's Mate stands fourth in the list of petty Officers in Her Majesty's Navy, and must be confirmed on examination in gunnery on board the *Excellent*.†

Gunners, Seamen, are instructed in the theory and practice of gunnery and great-gun exercise after having been entered in Her Majesty's Service for five years—they are qualified on board the *Excellent*, and are borne on the books of Her Majesty's ships as *Seamen Gunners*, for which they have additional pay.

GUNNERY,‡—(*See* "PROJECTILES")—The art of using fire-arms; but the term is commonly understood as being restricted to the use, or application to the purposes of war, of the larger pieces of ordnance, as cannon, mortars, and howitzers. In its practical branch, Gunnery includes a just knowledge of the construction of the several pieces of artillery, and of the strength, tenacity, and resisting power of the materials of which they are formed; of the method of mounting them upon strong, efficient, well-proportioned, and conveniently constructed carriages; of the proportions due to the strength of the powder and projectiles they should carry; of the force and effect, and also of the manufacture of gunpowder; and, generally, of all such mechanical arrangements and appliances as may facilitate the movements and working of the guns, etc., when prepared for action. But Gunnery takes a yet far more extensive range; for it may be said to be based upon nearly every branch of the mathematical and physical sciences, and may be itself considered as a science requiring the most intricate combinations of human knowledge and mechanical ingenuity fully to comprehend and perfect. It particularly requires an acquaintance with all experiments which may have been made to ascertain the impetus of projection, the momentum of bodies in motion, and the range and time of flight of projectiles with given charges of gunpowder,—with the effect of the resistance of the atmosphere upon projectiles propelled with different velocities, and the laws of gravitation as affecting falling bodies: and with the various causes, mechanical and otherwise, of the usual deflection of projectiles in their course, when fired from a gun.

Upon the practical portion of the art but little need here be written; for so various are the subjects which would require notice, that to treat of each in detail, a mass of matter must of necessity be given which would occupy more space than could

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* Queen's Regulations for the Naval Service. † Admiralty Instructions.

‡ By Lieutenant-Colonel Dundas, C.B., Royal Artillery.

be allowed in a work of this nature; and, for the like reason, it would be still less possible to be discursive upon all those points of philosophy which are embraced within the vastly extended circle of the Science of Gunnery. Some observations however upon what may be deemed its history, or the progress it has made up to the present time, may not inaptly here be given.

Previous to the invention of gunpowder, machines for thowing stones, spears, arrows, and burning materials, were in use for the attack and defence of towns, fortresses, and ships; and these, which had at an early period assumed the name of Artillery, so continued until the thirteenth century, though the smaller pieces of artillery, cross and long bows, were retained for the purposes of war long afterwards. All those implements however gave place to hollow* cylinders of wrought iron, of clumsy and inconvenient form and structure, without trunnions, and made to load at the breech, from which, at first, masses of small stones and balls of the same material, of, in many cases, prodigious weight, were thrown by means of very imperfect and weak gunpowder, which was long used in the ungrained state. And these latter, in their turn, gave place to the more modern cannon cast in bronze and iron, lighter, and much more easily manageable, from which iron balls of smaller size and weight, but with infinitely greater velocity and correctness, were thrown.

Gunpowder was, as before noticed, first employed in the ungranulated state; but when the danger, inconvenience, and loss of power arising from its being used in that condition became apparent, it was brought into the form of grains, at first, from the difficulty and slowness of the operation, and the comparatively small quantities so manufactured, to be used with small arms only; and after an interval of many years, when the process of granulating was rendered more easy and expeditious by improved mechanical arrangements, for the general purposes of artillery.

Long after the invention of gunpowder, Gunnery appears to have been considered as a mere practical operation, to which the small amount of general science then existing was in no way directed; nor does it appear that it excited the attention of philosophers until Nicholas Tartaglia, an Italian who lived in the sixteenth century, attempted to bring science to the aid of the art; though little advantage was derived from his labours and those of other philosophers of that period, from the general crudeness and incorrectness of their ideas on the motion of projectiles, and the circumstance of the theories formed by them never having been brought to the test of experiment. But the masculine and original mind of Galileo enabled him firmly to grasp the subject, and he it was who first attempted to resolve it into a science. He applied to Gunnery those laws observed by nature in the production and composition of motion, and was the first who correctly described the effect of gravity on falling bodies, or the tendency of ponderous masses of matter to descend to the earth from a place of rest above its surface; and on those principles he showed that the course of a cannon-ball fired from a gun would be in the curve of a parabola, unless it should be diverted therefrom by the resistance offered to it by the atmosphere; but he was unable to determine by experiment the amount of that resistance, and he left to those who might follow him the solution of that most important problem.

From the time of Galileo to that of Newton, the hints thrown out by the former as to the probable retardation of a projectile from atmospheric resistance were neg-

* The first fire-arms used in the field were made to load from the chamber, and this arrangement was extended, as stated in the text, to large cannon; but either anterior to or coeval with the cylindrical cannon was the ancient bombarb of a conical form, from which were projected large stone shot. The term bombarb is very ancient, having been used anterior to the application of gunpowder to projectiles. — *Editors.*

lected, or rather were wholly overlooked; and without further question or consideration, it was generally assumed that such resistance would produce no great effect, as the extreme rarity of the air would be as nothing when compared with the ponderous masses of shot in projection; and without attempting any experiment to prove the correctness of their views, disregarding wholly the expressed opinion of Galileo, they deemed it an established maxim that the course of projectiles was very nearly in the curve of a parabola, and that any departure therefrom was too trifling and insignificant to be attended to in calculation.

The master mind of Newton however readily detected and dispersed the errors of those who preceded him: he showed that in the usual high velocities of military projectiles, the resistance of the air increases nearly as the squares of their velocities, and proved that the track of projectiles passing through the air with swift motions, varied greatly from the parabola.

After Newton's time, nothing further was done towards the establishment of a just Theory of Projectiles until our countryman, Benjamin Robins, demonstrated clearly that the resistance of the air to bodies moving in it, is much greater than Galileo imagined, and that it could not be neglected as an opposing power in Gunnery; and he gives three different cases of resistance in a uniform medium.

1st. When it resists in the ratio of the velocity.

2ndly. When it resists in the duplicate ratio, or as the square of the velocity.

3rdly. When it resists partly in the ratio and partly in the duplicate ratio of the velocity.

The second case however agreeing more nearly to that which takes place with military projectiles, is alone considered in calculations in Gunnery; and he further determines the proportion between the times of ascent and descent of bodies; but it is to be regretted that he did not ascertain the path which a body would describe under the influence of the two motions. After Newton, the labours of Bernouilli were directed to the same point, but with the like result, as the only knowledge we derive from them is, that all rules which can be applied are insufficient, and that the ever-varying force of resistance prevents our obtaining an exact solution of the important problem.

In the year 1742, Mr. Benjamin Robins, who had early applied himself to making experiments in Gunnery, which were conducted with much patience, labour, and ingenuity, published his work entitled 'New Principles of Gunnery,' wherein he treated not only of the resistance of the atmosphere, but likewise of the force of gunpowder, and of the effects of guns of different lengths and weights, and of almost every other thing which in any way related to the motion of projectiles, carrying the Theory of Gunnery which he established upon the results of carefully conducted experiments nearly to its utmost perfection. He showed, or perhaps rather attempted to prove, that the great effect of gunpowder was due to the disengagement of a highly elastic fluid in a greatly condensed state in gunpowder, which, on combustion, became liberated, and expanding with amazing quickness and force, violently impelled balls and other matter opposed to it. Having, as he supposed, determined the propelling force of gunpowder, he proceeded to the determination of the effects it will produce upon, or the velocity with which it will propel, a projectile from a gun.

We will here give Robins's own account of the machine by which he measured the velocities of balls, which is simply a pendulous block of wood suspended freely by a horizontal axis, against the end of which were fired the balls whose velocities he determined "to such a degree of exactness (which may be augmented, too, at pleasure) that in a bullet moving with a velocity of 1700 feet in a second, the error in

the estimation of it need never amount to its 500th part, and this without any extraordinary nicety in the construction of the machine."

With this instrument, "if the weight of the projectile be known, and likewise the respective distances of its centre of gravity and its centre of oscillation from its axis of suspension, it will thence be known what motion will be communicated to this pendulum by the percussion of a body of known weight moving with a known degree of velocity, and striking it at a given point; that is, if the pendulum be supposed at rest before the percussion, it will be known what vibration it ought to make in consequence of such a determined blow; and on the contrary, if the pendulum, being at rest, is struck by a body of a known weight, and the vibration which the pendulum makes after the blow is known, the velocity of the striking body may thence be determined: hence, then, if a bullet of a known weight strike the pendulum, and the vibration which the pendulum makes in consequence of the stroke be ascertained, the velocity with which the ball moved is thence to be known." The rules for the calculation of which may be seen in the works of Robins, Euler, Antoni, and Hutton, to which we refer our readers.

By the machine described, Robins made many experiments, from which he arrived at most important conclusions; indeed, by its means he determined nearly everything relating to the true Theory of Projectiles and the Practice of Artillery.

It may be well here to note that the material fired at, a block of wood, was subject to much destruction from being used, and required compensation to be given for the addition to its weight by the shot or parts of shot which remained in it, and the pieces or wedges of wood which required to be driven into the centre of the block to produce a fair surface to receive the succeeding shot; but in consequence of the inconvenience and delay arising from the described operation, of late years cones of gun-metal have been used, which, after every shot, are refilled with sand, brought to a certain degree of dryness and weight, and, in order that it may be more effectually retained, covered over with a thin plate of lead. This arrangement, for which, as we understand, we are indebted to Piobert, an Officer of Artillery of much celebrity and distinction in France, would probably be adopted by us in England, in the event of any experiments with the Balistic pendulum being required to be carried on.

To the learned and very valuable commentaries of Euler upon Robins's publication, the science of Gunnery is greatly indebted; for independently of the original views taken of the subject, the new theory was brought thereby more generally to the notice of the scientific world, and greatly enlarged upon, omissions being supplied and corrections added where considered necessary. Euler also attempted the investigation of the nature of the curves of projectiles, and formed Tables for the solution of all cases which occur in Gunnery, but unfortunately the calculations resulting from his theories have but little accordance with practical results. Indeed, his description of the curve in which a projectile moves is so extremely perplexed, that no deduction, upon either philosophical or mechanical principles, can be made from it.

The laws and deductions made from the Balistic experiments by Robins and Hutton, with which all artillerymen should be acquainted, are considered as little necessary by the mere practical man, who, with Tables of Ranges, is, it must be admitted, able to perform with effect all ordinary service that may be required of him; but a just knowledge of the principles of the science of Gunnery is nevertheless indispensable; for without such knowledge, important points of construction and laws and deductions obtained from practice are lost sight of.

We have endeavoured, in the former part of this Paper, to show how various are the subjects of a scientific nature which have reference to Gunnery; and, without attempting any lengthened elucidation, we shall be satisfied in giving a brief digest of

what may be considered as absolutely necessary to be held in remembrance by the practical Artilleryman.

I. THE PROPERTIES OF MATTER TO BE CONSIDERED IN REFERENCE TO GUNNERY.

Inertia is that property of matter by which it will remain at rest until put into motion by the application of force; or, being in motion, will continue in motion until stopped by an opposing force.

Gravity is the tendency of all bodies towards the centre of the earth. The force of gravity is in the inverse proportion to the square of the body's distance from the centre of the earth.

Weights of Bodies are as their quantities of matter.

Specific Gravity of Bodies is their comparative weights under equal bulk.

Density of Bodies is the greater or less quantity of matter contained in the same bulk. In common parlance, bodies are said to be more or less heavy when their density is greater or less.

II. MOVEMENT OF BODIES.

Momentum of a Body is the product of its velocity and weight.

Velocity of a Ball is the measure of its flight, and is estimated by the rate per second at which it passes through the air.

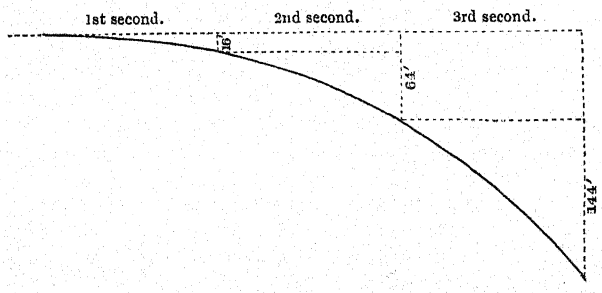
Its *Initial Velocity* is the rate at which it quits the muzzle of the gun; but this can only be practically ascertained when it has arrived at a certain short distance from the gun.

Its *Remaining Velocity* is its velocity when it strikes the object aimed at.

It is impossible to ascertain velocities with perfect exactness; but as the science of Gunnery requires that those points should be ascertained as nearly as possible, it had long been the object of philosophers to determine them, or to make as near an approximation as possible to the truth; and, as we have before shown, the very original contrivance of the Balistic pendulum by Robins has removed many of the difficulties which stood in the way of perfect success in this matter.

III. THE PARABOLIC THEORY.

A projectile in free space having been impelled by a charge of gunpowder from a piece of ordnance, will continue to move in the direction in which it was impelled through equal spaces in equal times, being continually drawn by gravity towards the



earth: but the projectile will fall precisely in the same time that a similar body would if let fall from a place of rest; and, while the force with which it was impelled is operating in the direction in which the piece was laid, it continues to fall by the

action of gravity through spaces proportioned to the squares of the times. Bodies fall through 16 feet nearly in the first second of time; and, as before said, the spaces being as the squares of the times, that passed through at the end of the second second will be 64 feet; at the end of the third, 144 feet; and at the end of the fourth, 256 feet. See the preceding diagram in explanation.

The properties of the parabolic curve being known, it was supposed to be easy to calculate the flights or ranges of projectiles, but practice disagrees most widely with the theory, for the atmospheric resistance is continually retarding the projectile; and the parabolic theory, however beautiful in itself, is practically inapplicable in Gunnery, and is only useful in demonstrating, by comparison with results in practice, the quantum of atmospheric resistance.

IV. LAWS AND RULES OF GUNNERY DEDUCED FROM EXPERIMENT AND PRACTICE.

The atmosphere presses alike upon any body at rest, equally and in every direction: if a ball move with any great velocity through the air, the air in front is condensed, and it is rarefied or forms a partial vacuum behind; hence, not being in equilibrio, being pressed upon from before, it meets with retardation in proportion to the square of its velocity; and not until the velocity is reduced to about 1400 feet per second does the displaced air return freely to fill the vacuum; but 1600 feet is the maximum velocity that should be given to a projectile, and that or any greater velocity is supposed to be reduced to about 1400 in passing over about 400 feet of space.

By the Parabolic Theory, greater or less bodies of equal densities, propelled with equal velocities and elevations, have equal ranges; but in practice it is not so: the retardation of small is greater than of larger bodies, because the resistance being upon the surfaces, is as the extent of those surfaces, which is as the squares of their diameters; whilst their power to overcome resistance is as their weights or the cubes of their diameters: hence the force to overcome atmospheric resistance increases faster than the resistance increases, and the larger is less opposed than the smaller ball. It is obvious that balls of greater density are less retarded than those of less density of the same diameter; for their surfaces being equal, the resistance to them is so likewise; but the power to overcome the resistance is greater in the denser body, and its retardation is therefore less.

Solid shot, propelled with equal velocities and elevations, range according to their weights; that is, the heavier ball will have the greatest range: hence solid shot outrange hollow shot when of the like diameter, because of the inequality of their weights.

Shot of equal weights and diameters, propelled with different velocities, will range according to their velocities, but not in direct proportion thereto, for the retarding power varies as the squares of the velocities.

V.

Velocities of shot increase with the charges in the ratio of the square root of the charge to a certain point, but diminish with largely disproportioned charges.

Velocities of shot from guns of equal weight, with equal charges, increase in a ratio between the square and cube roots of their length, to a certain limitation of length.

Velocities of shot of the same diameter, but of different weights, are inversely as the square root of the weights.

Penetrations of shot of equal diameter are as the square root of the charges.

A law has been deduced from experiment, showing that the accuracy of balls, or the probability of their hitting at distant ranges, is as the squares of their diameters.

At 1000 yards the 68-pounder should strike 15½ times.

,,	42	,,	,,	11 ,,
,,	32	,,	,,	9½ ,,
,,	24	,,	,,	6 nearly.
,,	12	,,	,,	5 times.
,,	9	,,	,,	4 ,,
,,	6	,,	,,	3 nearly.

By Dr. Hutton's rule for ascertaining the remaining velocities of shot, we have for the 32-pounder, with an initial velocity of 1600 feet per second, at 500 yards from the gun, 1126; at 1000 yards, 815; at 1500 yards, 608; at 2000 yards, 465; and at 2500 yards, 367: with these as data, we have an easy means of ascertaining the remaining velocities of other natures of ordnance.

VI.

As a general law of nature, action and re-action are equal, and in contrary directions. In gunnery, the charge of gunpowder, on expansion, acts upon the gun and shot with equal power, of which the recoil of the one and the range of the other are familiar examples.—But to explain, the elastic fluid generated on combustion is reacted upon by the shot, and the gun is forced to recoil with considerable momentum; but with a gun light in proportion to the weight of its projectile, the velocity of its recoil increases, and is violent in proportion to its lightness.

The momentum of a gun in its recoil is of easy calculation, momentum being the product of weight into velocity.

The common charge of a 24-pounder gun of one-third the weight of its shot gives, say 1600 feet per second of initial velocity:

$1600 \times 24 = 38{,}400$, the momentum of gun and shot;

$\frac{38{,}400}{5600}$, or $\frac{\text{momentum by}}{\text{weight of gun in pounds,}} = 7$ feet per second, nearly:

with a lighter gun, of 3580 lbs., the velocity of recoil will be 10½ feet per second.

These calculations are made without reference to the weight of the carriage, which should be added to that of the gun in all calculations for recoil.

GUNPOWDER* is an explosive propellent agent, being an intimate mixture of saltpetre, charcoal, and sulphur, the proportions of which vary slightly in different countries, and according to the uses to which the powder is applied. The propelling power of Gunpowder is dependent on the rapid decomposition of the nitre into its component parts; the oxygen forms carbonic acid with the carbon in the charcoal, and the heat thus generated by ignition changes both this and the nitrogen into a large volume of heated gas. In a mixture of nitre and charcoal alone, the oxidation proceeds with comparative slowness: by the addition of sulphur, an augmentation of combustibility is gained, in consequence of its igniting at a very low temperature; the sulphur, also, by its presence, renders available for the oxidation of the carbon an additional amount of oxygen, viz. that which is united with the potassium, the latter being at once converted into sulphite upon ignition of the powder. The advantages of Gunpowder, as a propelling agent, over every other explosive material are, the comparative safety attending its manufacture and transport, and the gradual nature

* By Major F. Baddeley, R.A., Captain-Instructor, Waltham Abbey.

of its decomposition when compared with those materials, such as fulminating gold, silver, or mercury, etc. etc. In Gunpowder, the force resulting from the rapid evolution of gas in a confined space has sufficient time to overcome the inertia of the projectile, which is not the case with other explosive materials, the conversion of which into gaseous products is so instantaneous that nothing can resist the intensity of their explosive action. Other advantages suggest themselves in the use of Gunpowder, such as the comparative cheapness of the ingredients composing it, and the ease with which they may be obtained; for the sulphur and saltpetre are very abundant productions of nature, and the charcoal can be manufactured cheaply and with great facility, and if care is taken in the process of the fabrication of powder, little deterioration will take place on its exposure to heat or moisture.

Condensed air and steam have been used as propelling agents; but the great inconveniences attending their use quite preclude the possibility of adapting them to war purposes.

By long experience and practice, it is found that the powder best adapted for the use of Artillery and Infantry is composed of the following proportions of the three ingredients, viz. 75 nitre, 15 charcoal, and 10 sulphur, in 100 parts, which proportion is closely adhered to in this country. The proportions indicated by theory for the production of powder of the greatest intensity would be more nearly represented by the proportions, 75 nitre, 12·5 sulphur, and 12·5 charcoal; these proportions are adopted in some Continental manufactories. Experience has however established real advantages as resulting from the employment of a somewhat larger proportion of charcoal (15 parts), and a reduction of the sulphur from 12·5 to 10.

Blasting powder contains a greater proportion of charcoal, and less saltpetre; its action, consequently, is much slower, which makes it more efficacious than Gunpowder for this particular use, at a great reduction in price.

PURITY OF INGREDIENTS.

The greatest care is requisite in the purification of the ingredients composing Gunpowder. A short description of the different processes by which we arrive at this result may not be uninteresting.

SALTPETRE, OR NITRE,

The principal ingredient in Gunpowder, is an abundant production of nature, and is a combination of nitric acid with the vegetable alkali; it is never found pure, being always contaminated with other salts and earthy matter; it is principally found in the East Indies, Ceylon, and South America, and is sometimes produced from decayed animal and vegetable matter; it is totally unfit for gunpowder until it has been refined; for, being combined with muriates of soda, lime, magnesia, and other salts which absorb moisture, the close contact of the ingredients would be deranged by their presence, the strength of the powder weakened, and the power of resisting the action of the atmosphere greatly lessened. As for the effloresecent salts it may contain, they are noxious only inasmuch as, possessing no particular useful property, they interpose their atoms between the more combustible ingredients, and impede the rapidity of deflagration.

There are two methods of refining saltpetre at Waltham Abbey:—1, the Old Method, of re-crystallizing three times; and 2, the New Method, which has only just been adopted, both of which we shall here briefly describe.

OLD METHOD.

About 35 cwt. of the grough saltpetre, as it is termed, viz. as it is imported in its

impure state, is put into a copper capable of holding 500 gallons, with 270 gallons of water, in the proportion of about 1½ lb. of nitre to 1 lb. of water (which proportion varies with the quality of the saltpetre), this is allowed to boil, and the impurities are skimmed off as they appear on the surface; cold water is occasionally thrown in to precipitate portions of the chloride, which otherwise would remain on the top by the action of boiling: after being allowed to boil from three and a half to four hours, the furnace doors are thrown open, when the chlorides and salts fall to the bottom. In about two hours, a copper pump is lowered into the liquor, which is pumped out into a wooden trough, having four or five brass cocks, under which are suspended canvas filtering bags in the shape of a V; the solution is then filtered and run off into pans containing about 36 gallons, and allowed to remain for twenty-four hours, to crystallize, when they are set up on edge, to drain off the liquor which remains uncrystallized, and which is called mother liquor. The saltpetre thus obtained is called once-refined, and undergoes the same process twice again, the only difference being that there is a greater proportion to the water each time, viz. 1¾ lb. to 1 lb. of water the second time, and 2 lb. to 1 lb. of water the third time: moreover, the third time, a small quantity of ground charcoal is put into the solution, and it passes through double filters, which brings it to a very fine pure white colour when melted. The mother water which remains in the pans after each crystallization is conveyed away by gutters to cisterns under the building, it is then evaporated in iron pots to one quarter of its original bulk, filtered, and allowed to crystallize. The saltpetre obtained from the first mother water is considered one stage inferior to grough; that from the second, equal to grough; that from the treble-refined, equal to once-refined saltpetre. The water left from every stage is treated in the same way, so that actually nothing is lost of the pure material. Saltpetre treble-refined by this process is perfectly pure, and fit for the manufacture of Gunpowder; and in order to free it from moisture, as well as for the convenience of storage and transport, it is melted in iron pots holding about four cwt. by raising it to a temperature of 600° Fahrenheit, and cast into gun-metal circular moulds holding about 38 lbs. each. It must be observed that it requires about two hours to bring the saltpetre into a liquid state, and that, after this, the furnace doors are thrown open, to lower the heat to the proper temperature for casting into the moulds. When the cakes are cold, they are packed away in barrels containing 1 cwt. 1 qr. each, and put into store. Care must be taken, in melting the saltpetre, not to raise it to too high a temperature, as this would reduce the quantity of oxygen, and form nitrite of potash, which would render it unfit as an ingredient in the composition of Gunpowder.

An exceedingly delicate test for the purity of saltpetre is made as follows:—Dissolve a small portion in a test-tube or small phial with distilled water; add a few drops, first of nitric acid, then of nitrate of silver; if no discoloration takes place, the nitre is pure. Should a milkiness appear, it indicates the presence of a chloride (common salt). To determine if the saltpetre has been over-heated, and consequently if it contains nitrite of potash, add a drop or two of the sulphate of copper: if a green colour appears, it is a certain indication that it has been brought to too great a heat in the melting process.

NEW METHOD.

Forty cwt. of the grough saltpetre is put into a copper with 270 gallons of water, and treated in precisely the same way as we have before described for the first refining; it is then filtered, and run off into large troughs, about 10 feet long by 6 feet wide, and 9 inches deep, lined with sheet copper; this liquor is then kept in a state of agitation by a wooden rake, until nearly cold: by this process a large quantity of

very minute crystals are formed, which are collected as they form by a wooden hoe, and shovelled with a spade on to a framework covered with copper sieving resting on the opposite sides of the trough, and allowed to drain; these fine white crystals, which have exactly the appearance of snow, when they have drained sufficiently, are raked over into a washing cistern adjoining, which is about 6 feet long, 4 feet wide, and 3 feet 6 inches deep, and fitted with a false wooden bottom that can be removed at pleasure. Cold water is allowed to run on to the saltpetre in this cistern till it is nearly level with the top; after remaining for an hour, it is drained off, and filled again with fresh water, which is drained off after about another hour; the saltpetre thus obtained is perfectly pure, and equal in every respect to the treble-refined by the Old Method. The water remaining in the cisterns after agitation is left till the next morning, when a quantity of larger crystals are formed on the bottom and sides; these are equal to once-refined by the Old Method, and are used with grough; the mother-liquor is then drained off, and evaporated in the usual way: the water from each washing is conveyed into cisterns, and used with grough saltpetre instead of water; but, as it contains a small portion of saltpetre in solution, a lesser quantity of grough is used to make the proportions correct.

Drying.—The saltpetre flour however contains a certain degree of moisture, which has to be dried off in the following way: two large copper trays, about 10 feet by 6 feet, with a 3-inch rim, are fixed over flues heated by a furnace, 4 inches of sand being between the flues and the bottom of the trays: the saltpetre is spread about 2 inches deep all over, and raked about till dry; it is then barrelled up for use. It takes about two hours to dry 5 cwt.

On comparing the two systems, there cannot for one moment be a doubt as to the immense advantages of the latter over the former. As an example, in the refinery where this new process is carried on, the result (that is to say, pure saltpetre) is obtained in one day instead of six, with less than one-half the amount of labour and coals. The extraordinary saving in the expense of apparatus will be seen by perusing the following table:—

To produce 23 *Cwt. a Day.*

OLD METHOD.		NEW METHOD.	
Crystallizing pans, 36 gallons (copper)	375	Crystallizing pans	50
Coppers, 500 gallons	3	Coppers, 500 gallons	1
Evaporating pots	4	Evaporating pots	2
Melting pots	4	Cisterns { Copper	2
Moulds, gun-metal	20	Cisterns { Wooden	1
		Drying trays	2
Filtering apparatus, sets	2	Filtering apparatus, set	1
Pumps, copper	6	Pumps, copper	2

In addition to this, there is ample room in the present building to erect two more sets of apparatus, which would then refine 69 cwt. in a day, against 23 cwt. by the old process.

On reflection, the reason of the great gain of time by this process will suggest itself; in the former method, when allowed to remain quiet, the crystals formed are very large, and the spaces left in them always contain a certain amount of mother water, which necessitates its being crystallized three times to perfectly free it from this liquor: in the latter, the crystals are so minute that there is practically no space for the mother-water to collect; consequently, by careful washing, the saltpetre is obtained perfectly pure.

CHARCOAL.

Charcoal is the next most important ingredient in Gunpowder; it is vegetable matter changed from its original nature by a chemical process, by which it becomes applicable to a special purpose. Wood charcoal is the woody fibre that remains after the liquid and more volatile parts have been driven off by the fire in the process of charring; the temperature resulting from the combustion of charcoal is much higher than that from burning wood, in consequence of the absence of the large quantity of water which wood contains, amounting to between 50 and 60 per cent.; the object, therefore, of charring wood is the removal of moisture, and also, what is of great importance, the expulsion of those matter contained in it which become volatile before they are burned, thus rendering a large amount of heat latent. The woods generally used in this country in making charcoal for Gunpowder are, the alder, willow, and dogwood. Other woods are sometimes used by English and foreign manufacturers, but none produce a powder of such quality as obtained from the above. It is usually considered that better charcoal is distilled when the wood is allowed to season for a time; but recent experience has shown that wood only lately cut and peeled, after being desiccated in a hot chamber, will make equally good charcoal with that which has been seasoning for three or four years.

All the wood which is cut in the Government grounds, or purchased from merchants, is stripped of the bark, on account of its being impregnated with salts and gummy substances, cut into lengths of 3 feet for the convenience of loading the iron slips, which are a little above this length, and stacked in the wood-yard. It is paid for by the cord, which is 14 feet long, 3 feet wide, and 3 feet high, containing 126 cubic feet. The method of charring is performed in the following way:—

Cylinder Charcoal.—Cylindrical cases of the required size, fitted with lids, are filled with wood: these cases are made to fit easily, and slide horizontally into iron retorts built in the wall, which admit of accurate regulation of heat (communicated to them by furnaces underneath) throughout the operation of charring; a great saving of time and heat is effected by their use, as when the wood has been properly charred, the case or slip containing it may be easily withdrawn, and another containing a fresh charge at once introduced into the retort, without allowing the latter to cool down, as would otherwise be necessary. When it has been sufficiently charred (which is known by experience, in watching the burning of the gas that is produced and is conducted into the fire), the slip is withdrawn by tackling, and at once lowered down into iron coolers or cases, which are immediately covered up with close-fitting lids, and then allowed to remain until all fire is extinguished. The goodness of charcoal is an essential point in the manufacture of Gunpowder; about twenty-five to thirty per cent. is obtained; and one cord will produce about four cwt. of charcoal: if properly charred, it should have a jet-black appearance, and when powdered, a lustre resembling velvet; it should be light and sonorous when gently dropped, and its fracture should exhibit the same appearance throughout; it should be so soft as not to scratch polished copper, and ought not to exhibit any alkali when treated with pure distilled water. The alder and willow charcoal are easily distinguished from each other, the former having a triangular pith most distinctly marked, and the latter a circular one. Dogwood is charred precisely in the same way, as just described, and is purchased by the bundle of 27 lbs. weight, or thereabouts, each producing from 7 to 10 lbs. of coal; it is very much smaller than the alder or willow, averaging the size of thick osier; its pith is circular, and large in proportion to the size of the wood, exhibiting, when converted into charcoal, a yellowish metallic appearance. It is considered by many that this charcoal possesses peculiar properties which more particu-

larly recommend it for the manufacture of Gunpowder; I have however tried every experiment on this point, and find no difference between it and carefully-picked small alder or willow—the strength and cleanness of the powder arising more from perfect incorporation, purity of the ingredients, and proper distillation of the charcoal than from any other cause. Charcoal is very porous, and absorbs very greedily gases and moisture from the atmosphere; no large store therefore is ever kept, and particular care is taken to prepare it only in proportion as it is required for use. Before being used for gunpowder, it should be carefully picked over, as portions of dense coal are sometimes formed by the trickling down of tar which has condensed on the top of the retort. To ascertain if charcoal contains alkali, powder a small portion, add some distilled water, boil and filter the solution, apply litmus-paper that has been reddened by any weak acid, and, if it contains alkali, the original colour will be wholly or partially restored.

Pit charcoal, which is used for pyrotechnic compositions, and also as an ingredient in pit powder,* is burned in the following way:—from three to four cords of wood are built up in a circular mound about ten feet in diameter and five feet high, having a hole left in the centre, which acts as a chimney; this mound of wood is then covered with stubble or straw, about three or four inches deep, and over this a layer of charcoal-dust or sand, about the same thickness; some lighted charcoal is put down the chimney, which is then closed up, and the process of charring commences; a shifting screen is always placed to windward, to regulate the draught, and small holes are left at intervals, to allow the escape of the vapour; after three days and nights the operation is complete. The charcoal thus produced contains more of the woody fibre, and burns slower than that made in cylinders; it consequently is heavier, has a very slight reddish tinge, a more metallic sound when dropped, and breaks with greater difficulty. Great attention and experience are required in burning this charcoal, in consequence of which, men from the forests are generally employed who are charcoal-burners by trade.

SULPHUR.

This combustible elementary body is found generally in great quantities in the neighbourhood of volcanoes; it is also obtainable from metallic ores, and readily fuzes. At 170° Fahrenheit it begins to evaporate; at 185° to 190° it melts; at 220° it is perfectly fluid; and at 600° it sublimes. Sulphur is purified simply by melting: that which is supplied to Waltham Abbey has been once refined, and the following is a description of the apparatus and method for purifying and rendering it fit as an ingredient in Gunpowder. A large iron pot is set about three feet off the ground, or about the height that an ordinary boiling copper is placed, having a furnace underneath. This pot has a movable lid, which is fixed into the top of the pot with clay, and in which lid is an iron conical plug that can be removed at pleasure; from the pot lead two pipes, one to a large circular dome, and another to an iron retort rather below its level; the last-mentioned pipe has a casing or jacket round it, which can be filled with cold water; the communication of these pipes with the melting pot can be shut off or opened, as occasion requires, by a mechanical arrangement. About $5\frac{1}{2}$ to 6 cwt. of the once-refined sulphur is broken up into small pieces, placed in the iron melting pot, and subjected to the action of the furnace: the plug in the lid and the pipe leading to the dome are now left open, but the pipe to the retort closed; after from two to three hours a pale yellow vapour rises, when the plug is put in, and

* Pit powder is an ingredient in fuze composition; it is preferred for this purpose, from the fuzes being slower and more regular in burning than if made with common meal powder.

the vapour conducted into the dome, where it condenses in the form of an impalpable powder, commonly called flowers of sulphur: a small pipe leads from the bottom of the dome on the opposite side into water, to allow the escape of the air, and sulphuric acid is taken up by this water. In about one and a half to two hours after, the vapour becomes of a deep iodine-colour, when the communication with the dome is shut, and the one to the retort opened; at the same time, cold water from a tank above is allowed to pass into the jacket we have before mentioned surrounding this pipe; the vapour then distils over, is condensed in the pipe, and runs into the retort below in the form of a thick yellow fluid. When nearly all has distilled, which can be known by the jacket getting cold, the communication is again closed with the retort, and the fluid sulphur left an hour, to get sufficiently cool to ladle out into moulds, the furnace door and the communication with the dome at the same time are again thrown open, that the rest of the vapour may pass into the latter; the flowers of sulphur thus obtained are used for laboratory purposes, being unfit for the manufacture of Gunpowder, from the acid they contain, and the crystalline sulphur, after being allowed to cool in the moulds, is barrelled up and used as the third ingredient in Gunpowder. To ascertain the purity of sulphur, if a small portion is burned on a piece of porcelain, no residue should be left; also, if it is treated with distilled water, litmus-paper should not be discoloured.

Having explained in a concise manner, which is all that is necessary in the present Papers, the method of production and purification of the ingredients, the next thing to be considered is, their fabrication into Gunpowder.

PULVERIZING THE INGREDIENTS.

The three ingredients are now ground separately to a very fine powder: the mills which effect this and incorporate are so similar, that a description will be given under the head of "Incorporation." After being ground in this way, the saltpetre is passed through a slope cylindrical reel, covered with copper sieving wire of 60 meshes to the inch, which, as it revolves, sifts it to the required fineness, being then received in a box or bin underneath: the charcoal and sulphur are likewise passed through similar reels of 32- and 60-mesh wire respectively, and that which remains without passing through, is ground again under the runners. A very excellent machine has been invented by Mr. Hall, the engineer of Dartford, for grinding charcoal, which makes a most useful addition to the Gunpowder factory; it consists of a conical drum, working in a conical box, on the same principle as a coffee-grinding machine, the axis being vertical; the mill is fed with charcoal by a hopper, and, as it passes through in a fine powder, falls into a revolving reel, which sifts it in the same manner as before described, the whole being covered in, to prevent the great annoyance of dust which was felt until lately from the old charcoal mill. The three ingredients having been pulverized, are now fit for the mixing process.

MIXING THE INGREDIENTS.

The ingredients are now weighed out very accurately, in the proportion of 75 nitre, 15 charcoal, and 10 sulphur, in 42-lb. charges,* viz. nitre 31 lbs. 8 oz., charcoal 6 lbs. 4 oz. 13 drs., sulphur 4 lbs. 3 oz. 3 drs., and thoroughly mixed in a machine which

* The gunpowder merchants always use fifty pounds in each charge: this quantity of forty-two pounds was first fixed upon many years ago, and is considered by some to possess important virtues, which however I have never been able to discover; moreover I have proved by experiment, that charges of fifty pounds will make equal powder in every respect, and, I consider, with great

consists of a cylindrical gun-metal or copper drum, about two feet in diameter, with an axle passing through its centre, on which there are metal flyers, like forks: the machinery is so arranged that the flyers and drum revolve in opposite directions when in motion, at a rate of about one hundred revolutions per minute: five minutes is sufficient for a thorough mixture; the composition is then drawn off by a slip into canvas bags the proper size to hold the 42-lb. charges, which are tightly tied, and taken to small magazines. These are called green charges, and are now ready for the next process, incorporation.

WET MIXING.

A plan has been patented by Mr. Drayson, of Maresfield, Sussex, for mixing the ingredients wet, in the following way:—The proportion of saltpetre is put into a pot with about twelve pints of distilled water, and brought to the boil either by steam or an arrangement of flues, it becomes then a solution of saltpetre; the charcoal and sulphur are next added, and the whole mixed together, so as to form a stiff paste; it is then turned out into bags, and goes through the ordinary process of manufacture; the charcoal, by this means, appears actually to imbibe the saltpetre, and the mixture must be far more intimate than by the former method. Should a quick and safe arrangement be matured which will enable this plan to be carried out, it will add greatly to the capability of an establishment, as, from experiment on a small scale, it has been fully proved that the ingredients mixed in this way require only half the time of incorporation, and produce a powder as strong and good in every respect as by the present process.

THE INCORPORATING MILL.

The Incorporating Mill consists of an iron or stone circular flat bed, about seven feet in diameter, fixed very firmly in the floor of the building which covers it, whereon two iron or stone cylindrical runners from five to seven feet in diameter, fourteen to eighteen inches wide, and each weighing from 3 to 4½ tons, revolve; they have a common axle, and a vertical shaft passing through the centre of the bed is connected with this axle, and to machinery above or below, which communicates the motion. These runners are not equidistant from the centre, by which arrangement in their revolution every part of the composition on the bed is subjected to their action, which is threefold, viz. crushing, grinding, and mixing; crushing, from the weight of the cylinders; grinding, from the twisting motion which they are forced into from so large a diameter revolving in so small a circle; and mixing, from a combination of the two former motions. To prevent the powder from falling over the side of the bed, a wooden rim, about two feet in height, is placed at an angle of forty-five degrees with it, like the side of a funnel, and fitted closely all round its circumference: this is called the "curb;" and in the centre of the bed, a gun-metal ring, or "cheese," as it is termed, about two feet in diameter, and five inches high, concentric with the bed, prevents the powder working beyond in that direction: moreover, two scrapers, or "ploughs," connected by stays with the horizontal axle, revolve with the runners, one rubbing against the inner, and the other the outer circle; these ploughs are made of hard wood, shod with leather and felt, and their use is continually to disturb and rout about the composition, and keep it under the path of the runners,

additional safety in the manufacture; for I am convinced that nine-tenths of the explosions which occur in this process proceed from there not being sufficient composition on the mill, whereby the surfaces of the runners and beds occasionally come in contact with each other, causing immense friction; there are many opinions as to the cause of these explosions in this particular stage of manufacture; no reason I have ever heard accounts for them so satisfactorily, or points so clearly to the remedy.

so that every part should get its share of incorporation. The houses or sheds which cover these buildings have hitherto been constructed of wood, with either corrugated iron or wooden roofing. The new incorporating mills in this factory, which are just completed, are built with three sides of strong three-foot brickwork, and the fourth side and roof of corrugated iron and glass; they are also placed in a line contiguous to each other, the alternate ones only facing the same way, so that an explosion from one would probably communicate no further, and the lighter parts of the building would blow away, leaving the rest entire. Most of the machinery in the factory is driven by water-wheels; the motive power of these mills is steam.* A horizontal shaft worked by the engine passes underneath the entire length of the building in a cast-iron tank, and a bevel wheel on this shaft is geared into another one on the vertical shaft under the centre of each bed, which, communicating with the runners, gives the necessary motion. A very perfect arrangement is made, by which each pair of runners may be stopped or set in motion independently of the others, and without any sudden or jerking movement, which would be likely to cause explosions; it is managed in the following way:—

An iron drum is cast in one with the bevel wheel, which is loose on the horizontal shaft; two segments, edged with copper, are keyed on to this shaft, which are made to expand or contract at pleasure inside this drum, by the action of a lever. These segments being keyed to the shaft, always revolve with it, and when made to expand into the drum, the friction imparts the same motion to the bevel wheel, and consequently to the vertical shaft in connection with the runners.

In order, as much as possible, to guard against any explosion spreading, above each bed, placed so as just to clear the runners, is suspended or balanced a copper tank, holding about forty gallons of water. On one side of the tank is fixed a small shaft, which communicates with similar cisterns over the beds of the mills on either side; the other end of the tank rests on a flat board, which is subjected to a great part of the force of an explosion; this consequently lifts, disengaging the support of the tank, the contents of which drench the bed which has just exploded, thereby putting out all fire, and cooling the machinery, besides having a similar effect on the mills right and left, preventing, by this means, any extension of fire.

INCORPORATING THE INGREDIENTS.

The charge is spread pretty evenly over the surface of the bed, and moistened with from four to six pints of distilled water; the quantity varying according to the state of the atmosphere; the runners are then set in motion, and run from seven to eight† revolutions per minute for three and a half hours, during which time the powder is often routed up by a copper-shod spud, and watered slightly with a fine rose watering pot, according to the experience of the millman; at the end of this time the mixture is thoroughly incorporated, possesses all the chemical properties of Gunpowder, and is taken off the bed in the form of a cake, varying from a quarter to half an inch in thickness, and of a blackish-grey colour. This is called "Mill Cake," and when broken, the fracture should exhibit the same uniform appearance, without presenting

* Care has been taken in providing a chimney of sufficient height to the boiler-house, which, with the further caution of always using anthracite coal, precludes the possibility of any accident from sparks, etc., falling.

† In the new Steam Mills, the engine is arranged so that from eight to fourteen revolutions can be given to the runners by merely altering, with a lever, the position of the friction-wheel on the main shaft, which works the governor. I consider that, without going to either extreme, many advantages will be gained by fixing the speed at ten revolutions, which will greatly reduce the time at present allowed for incorporation.

any sparkling or yellow specks; should this however be the case, it is a sign of the ingredients not being sufficiently incorporated. In this stage it undergoes certain proofs; samples of the cake are taken from every charge that is worked, dried in an oven, and granulated; half a drachm of this is fired in a vertical eprouvette, which it ought to raise 3·5 inches; and half an ounce is flashed on a glass plate; if very little residue or ash is left, it is an additional proof of its being well incorporated, and that the millman has done his work properly.

Incorporation is by far the most important process in the manufacture of Gunpowder; for, however carefully the other part of the fabrication is carried on, should there be a failing in this, the powder will be worth nothing.

The great and ultimate object to be attained in the manufacture of Gunpowder is, to produce that which shall give equal results with equal charges; the greatest regularity should therefore be observed in this stage. The millman should have great experience; the runners and beds should be, as nearly as possible, the same size and weight, and driven at the same speed throughout the factory; at any rate, each charge should be worked to the same number of revolutions; the motion of the runners should also be as uniform as possible, which is very satisfactorily accomplished by each water-wheel being regulated by a governor.

In one of the largest Gunpowder manufactories in England, a new method has been adopted in this process; the charge is constantly kept moist with boiling water by a self-acting apparatus; the bed of the mill is hollow, and made of iron, through which a constant supply of hot water or steam circulates from the engine boiler, which raises the temperature to about 170° Fahrenheit. It is considered by the manufacturer that this plan succeeds well, producing as intimate a mixture of the ingredients, with a saving of about one-third of the time. The new mills just completed are constructed so as to admit of the application of this principle, should it ever be considered advisable to adopt it.

BREAKING DOWN THE MILL CAKE.

The mill cake, after it comes off the bed of the incorporating mill, is placed in wooden tubs, and taken to small-expense magazines, and from there, in about twelve hours, to the breaking-down house; the object of the machine from which this takes its name, is to reduce the cake to a convenient size for the hydraulic-press box, and also that, by being crushed again to meal, it may get a more even pressure; it consists of a strong gun-metal framework, in which are fixed two pairs of fine-toothed or plain rollers, which revolve towards each other, working in spring collars, so that, on any hard substance getting in by mistake, they would open, and allow it to pass through, thereby preventing the dangerous friction which would otherwise result. A hopper, or upright wooden funnel, capable of holding about 500 lbs., is fixed at one end of the machine, and an endless canvas band 2 ft. 6 in. wide, having strips of leather sewn across at intervals of four inches, passes over one roller at the bottom of the hopper, and one at the top of the machine; when set in motion, this conveys the cake from the hopper to the highest point of the band; it then falls through the first pair of rollers, and from thence through the second, passing in the form of meal into small wooden carriages underneath, which, as they are filled, move forward by a self-acting motion, making room for others. The mill cake thus broken down, is fit for the press.

PRESSING THE MEAL BY THE HYDRAULIC PRESS.

The meal is now subjected to very powerful pressure; and, in order to explain the way in which this is effected, a short description of the apparatus must be given. The

principle of the hydraulic press is so familiar to most, that it will be unnecessary to do more than show how the power is applied.

A very strong oak box, 2 ft. 6 in. square, and 2 ft. 9 in. deep, is constructed so that two of the sides and the lid will fall back on hinges, or form a compact solid box when screwed firmly together. Forty-six copper plates, 2 ft. 5½ in. square, slide vertically into this box, and are kept five-eighths of an inch apart by two metal slips with corresponding grooves, which can be removed when necessary.

METHOD OF LOADING THE BOX.

About 800 lbs. of the meal is put into this box while the plates are in the position we have described. When full, the slips are withdrawn, the plates being then only separated by the powder between them: the lid is now firmly screwed down, and the box turned over by an arrangement of pulleys, so that the plates which were vertical will now be horizontal. The present upper side is then unscrewed, and a travelling crane, moving on a rail overhead, is lowered till the claws attached to it hook on to two trunnions fixed on the sides of the box; it is now hoisted by means of a hand-wheel windlass, and the box being suspended, is pushed easily, by means of the rail, and deposited in this position on to the table of the ram under the press block. The pumps that work the hydraulic press are in a separate house, a high traverse intervening: the men, after placing the box in the position in which we left it, retire to a room adjoining the pump house, and are in comparative safety in the event of an explosion. The pumps are now set in motion by a water-wheel,* and are allowed to work up to the required pressure, which is about seventy tons to the square foot. After this pressure has been obtained (which is known by the safety-valve lifting, and the water making its escape), the box is allowed to remain under the press for a quarter of an hour, a cock is then opened, which allows the free passage of the water from the cylinder, and consequently the descent of the ram; it is then conveyed from under the block in the same manner, and very easily unloaded, it being constructed, as we have before explained, so as to allow the top and two sides to fall back on hinges. The press cake is then taken out in layers between each plate, resembling dark pieces of slate, about half an inch in thickness; after a day or so, this hardens so much as to be difficult to break, and the appearance of the fracture resembles that of the finest earthenware. Many important advantages are gained by this pressure, of which the following are the principal:—

First, the density of the powder is increased, which prevents it falling to dust in transport, or by rough usage. Secondly, its keeping qualities are improved, for it withstands the action of the atmosphere, and absorbs less moisture than a porous light powder. Thirdly, it produces more grain in the manufacture than mill cake; and a less proportion, consequently, is lost in dust. Fourthly, a closer connection of the ingredients is obtained. Fifthly, a greater volume of inflammable gas is produced from a certain bulk, than from a corresponding bulk of lighter powder.

The range however is lessened, from a greater quantity being blown out of a gun unignited; but this small loss is more than counterbalanced by the former advantages, and actually it is only perceptible in newly-made powder; for a light, porous powder soon loses its superior range from its absorption of moisture, while that of the dense powder remains unaltered.

GRANULATING THE PRESS CAKE.

The next process is granulation, or reducing this press cake into the proper sized

* There is also an arrangement of levers, by which they can be worked by hand, if necessary.

grain for cannon, musket, or rifle powder; the machine which effects this is very beautifully contrived, and is entirely self-acting, obviating the necessity of any one being in the building while it is in motion. It resembles, in appearance and action, the breaking-down machine, except that it is larger, and is fitted with three pairs of toothed rollers of different degrees of fineness, working in the same kind of collars already mentioned, so that, on any hard substance passing through, they would open accordingly, and thus prevent friction. At one end of the machine is a wooden hopper, or funnel, which is filled with the press cake; this is contrived so as to rise gradually by the motion of the machine, and constantly to supply an endless band, similar to the one described in the breaking-down house. When the cake arrives at the highest point of this band, it falls over, and is granulated between the first pair of gun-metal rollers; under each pair is a screen covered with 8-mesh wire; all that is not sufficiently small to pass through, is carried on to the next pair of rollers, and, in like manner, that which does not pass through the second screen is carried to the third pair. In addition to these screens, there are three oblong sieves covered with 8- and 16-mesh wire, and 56 cloth respectively, fixed under, and parallel to, each other, each being separated by about four inches of space, running at an incline just below the three pairs of rollers; these all lead to little wooden carriages placed on the opposite side of the machine, which are divided so as to collect the different-sized grain as it passes down. To facilitate the separation and sifting of the powder, and to prevent masses of it forming and clogging up the wire, a shaking motion is imparted by a circular wheel attached to the framework of these sieves revolving against an octagonal one fixed to the machine. The grains which pass through each screen below the rollers fall on to the upper one of these three last-mentioned sieves; that portion which passes through this, and is retained on the 16-mesh wire, is cannon powder; that passing through the 16-mesh sieve, and retained on the 56 cloth, is fine grain; and a board running also parallel underneath retains the dust that passes through the cloth.

The "chucks," as they are called, or those grains that are too large to pass through these different sieves, are collected in the same way as the grain, and undergo the process of granulation again.

The hopper, having arrived at a certain height, and discharged its contents, rings a bell, which is a signal for the machine to be stopped and re-charged. The powder thus obtained is by no means finished, as it contains a good deal of moisture and dust, which have to be expelled and separated from it; it is called, in this state, "foul-grain powder."

DUSTING LARGE-GRAIN POWDER.

The keeping qualities of powder are very much improved by removing the dust, which quickly absorbs moisture from the atmosphere; this operation, for large-grain, is performed by cylindrical reels about 8 ft. 6 in. long, and 3 ft. 8 in. in diameter, clothed with 28-mesh canvas, which revolve at the rate of thirty-eight times per minute. Those for large-grain are called horizontal reels, in contradistinction to those for fine-grain, that are called slope reels; each is enclosed by a wooden case, to prevent the dust flying about the house. When the powder has run its time, one end of the reel is lowered; it then runs out into barrels placed to receive it. This entirely separates the dust, and imparts a fine black gloss, which is sufficient glazing for the large-grain powder. There however remains a certain degree of moisture; it has therefore to undergo a further process of being stove dried. Before however describing this next essential part of the manufacture, we must follow the course fine-grain has to go through till it is also fit for this operation.

DUSTING FINE-GRAIN POWDER.

The fine-grain powder has a much greater proportion of dust when it leaves the granulating house than the large-grain; and it is found necessary, on this account, to use a different kind of reel. They resemble those for the former powder, except that they are covered with 44-mesh canvas instead of 28, and are placed at an incline which prevents their being choked up with the quantity of dust; each end is also open, and a continuous stream of powder, fed by a hopper, passes through while they revolve, and pours out at the lower end into barrels. This process is repeated a second time, which sufficiently frees it from dust.

GLAZING FINE-GRAIN POWDER.

The fine-grain powder thus dusted, is then glazed for three hours in barrels capable of holding 300 lbs., which are 3 ft. 6 in. in length, and 2 ft. 8 in. in diameter, revolving at the rate of thirty-two times in a minute. By the mere friction of the grains against each other and the inside of the barrel, a glaze is imparted, presenting a fine polished surface to the grain.

Powder glazed in this way withstands the action of moisture to a far greater extent than unglazed powder, and in transport very little dust is formed.

An artificial glaze is sometimes given by the addition of a little lamp black or graphite in the glazing barrels; this plan is not however adopted in the Government works, as it is considered that these coatings might attract moisture. The small quantity of dust generated by this process, is removed by passing the powder again through similar slope reels to those before mentioned; these are called slope-reels for glazed powder, which are kept separate. The fine-grain is now in a similar state to the large-grain in the stage in which we left it. They both contain moisture, which it is necessary to expel before they are fit for the Service.

STOVING OR DRYING POWDER.

A drying-room, heated by steam pipes, is fitted with open framework shelves, on which rest small wooden trays about 3 feet long, 1 ft. 6 in. in breadth, and 2½ in. deep, having canvas bottoms; on each is spread 8 lbs. of powder. This room holds about 40 barrels, or 4000 lbs., which remains in it for twenty-four hours, and is subjected to a heat of 130° Fahrenheit for sixteen hours, communicated by steam passing through pipes arranged horizontally on the floor of the room. The temperature is raised and lowered gradually, otherwise the too sudden change would be likely to destroy the texture of the grain. The ceiling and roof are fitted with ventilators, through which all the moisture escapes, so that there is a constant current of hot air circulating through the room. It is of the greatest importance that the vapour should be carried off; for, if this is not effectually done, on the decrease of temperature, it would return to its liquid state, and form again on the powder.

FINISHING DUSTING.

The action of heat however produces a small portion of dust; both these powders, therefore, when they leave the stove, are reeled in horizontal reels, clothed with 28- and 44-mesh canvas respectively, for one hour and a half. This perfectly separates any remaining dust, and gives the finishing glaze to the large-grain powder. This is the final process, and the powder thus finished is taken to the barrelling-up house; weighed out into barrels holding 100 lbs. each; marked L. G. (large grain), and F. G. (fine grain), as the case may be; and stored in magazines.

The proportions of different powders obtained in the manufacture are as nearly as

possible, seven-tenths large grain, two-tenths fine grain, and one-tenth dust; all that is separated in each operation is worked over again for one hour under the runners, and goes through the remaining different stages of manufacture, the same as the regular work. That which is separated in the last dusting of the fine-grain, or musket powder, through the 44-mesh cloth, exhibits a beautiful uniformity of grain; after being reeled for an hour and a half in a 72-mesh silk, it is equal in appearance to the finest sporting powder, and is used to fill Captain Boxer's diaphragm shells. About 8 per cent. is obtained.

THE POWDER BEST ADAPTED TO THE ENFIELD RIFLE.

A great many experiments have been lately made, and particular attention paid, to ascertain the powder best adapted to the Enfield rifle. Hitherto common fine-grain powder, obtained by the method we have described, has been exclusively used; but it is a question whether one made with greater care, of more even grain, and pressed lighter, would not be better suited for rifle practice; the principal thing to be guarded against is the fouling of the piece, which prevents more than a limited number of rounds being fired without cleaning it. As far as experiments have been carried at present, it is considered that a powder made from small-wood charcoal, from one-half to three-quarters of an inch in diameter, incorporated for four hours, slack-pressed, and separated, so as to obtain an even grain, between a 16- and 20-, or 20- and 28-mesh wire sieve, will answer in all respects for this service better than any other.

EXAMINATION AND PROOF OF GUNPOWDER.

The great and ultimate object to be obtained in the manufacture of Gunpowder is, not so much to produce that which ranges the highest, as one that shall be durable in its texture, not easily deteriorated by atmospheric influence or transport, and one with which equal charges shall produce equal effects. It should present uniformity in the appearance of its grains,* which should be angular, crisp and sharp to the touch, not easily reduced to dust by pressure between the fingers, or dusty in handling; its specific gravity should not be under 55 lbs. to the cubic foot (that of Waltham Abbey is generally 58 lbs.) taking water at 1000 oz.; its strength is tested by firing three rounds from an 8-inch mortar, throwing a 68-pounder solid shot with a charge of 2 oz.—this should give a range of from 270 to 300 feet. The distance however varies considerably, according to the state of the atmosphere and the density of the powder: for, the greater the density, the less the range in small charges. Half an ounce flashed on a glass plate should leave little or no residuum; should white beads or globules appear, it is a sign of imperfect incorporation.

All these requirements are of paramount importance, particularly that which relates to the equal effect of given charges; for on this are based all calculations connected with gunnery, and the accuracy of artillery practice is entirely dependent on it.

Many reasons have been advanced why the Government should be their own manufacturers to a certain extent—such as the great saving in the cost of powder when compared to the price paid to the merchants, which in seven years of the war, from 1809 to 1815, from the Government having Waltham Abbey, Faversham, and Ballincollig, amounted to upwards of £300,000; and, had there been greater capabilities, more than double that amount would have been saved; also, by exercising

* The proportion of different sized grain in one pound of cannon powder has been fixed as under, viz.—

9 oz.	that will pass through an	8	sieve, and be held on a	12
5 oz.	,,	a 12	,,	16
2 oz.	,,	a 16.		

a control over the market, exorbitant demands are prevented, which might be made, were the Government not in a position to check this by their own establishments.

No reason however is so strong, or of such consequence, as the above, viz. the production of an equal powder, it being next to an impossibility to obtain this result—indeed, it cannot be expected—where the great bulk is supplied by half-a-dozen different contractors, none of whom pursue the same process.

The Government should therefore, I conceive, be in a position to manufacture for their utmost wants, at any rate all that does not come under the head of blank ammunition; the first outlay in buildings and machinery would be covered in a few years, and the service of artillery greatly benefited by the use of a powder that could at all times be depended upon. In the Government factory every particular in the fabrication is most carefully attended to, the purity of the ingredients always tested, and great attention paid to the proper distillation of the charcoal; they are always ground in the same way, and sifted to the same degree of fineness: in fact, every process is always carried on in precisely the same manner. The consequence is, that Waltham Abbey powder is considered by all the best sample to work to; on this point, Major Mordecai, in his excellent work, says,—"I would therefore propose the Waltham Abbey powder as the type or standard to which our* powder for military service should conform in nearly all respects. In this manufacture, the essential operations are—the separate pulverization of the ingredients, their incorporation by the cylinder mills alone, and the formation into cake by moderate pressure."

In addition to the above reasons of the advantages arising from Government factories, are the experiments that can be carried on, and improvements made, in producing a powder of superior quality. I cannot do better than quote a paragraph in the evidence of Lord Hardinge before the Finance Committee of the House of Commons in 1838.

He says:—"At Waltham Abbey, in a very few years after it was constructed, the powder was so improved, that the charge of powder to the weight of shot was reduced from one-half to one-third; therefore two barrels were used instead of three, an advantage in stowing on board ship, as well as in the field."

From the above, it will appear that a great part of the powder for H. M. Government has at present to be supplied by merchants. The contracts are made out sometimes for them to supply their own saltpetre, and at others for the Government to furnish it pure, at the rate of 77·5 lbs.† per barrel of 100 lbs., they finding the other materials and manufacture, a corresponding reduction in price being made; as however it has to come up, in nearly all respects, to the sample,‡ the requirements of which we have before stated, certain proofs have to be undergone before being received for the different services.

PROOF OF MERCHANTS' POWDER.

The following are the different proofs merchants' powder is subjected to:—

Lots of 100 barrels are sent in, marked with the number of the lot and the maker's name on the head of each barrel; 25 per cent. of these are unheaded in the examining house; the Proof Officer then—

First, takes a bowl out of each barrel, and holding it about three feet above, pours it out quickly; should there be a good deal of dust, it is satisfactorily shown by this means.

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* American.

† This allowance of 2½ lbs. extra is given to make up for losses, etc., in the course of manufacture.

‡ The merchants are provided annually with a sample of Waltham Abbey powder, to guide them in their manufacture.

Secondly, it is handled and pressed between the fingers, to test the firmness of its grain; and should there appear to be any great difference in the proportions of different sizes to that laid down as a standard, it is sifted and compared accordingly, being rejected should the quantities fall short or exceed the sample in any great degree.

Thirdly, a barrel or two are selected, and the powder poured into a hopper, under which is placed a box very carefully constructed, so as to hold exactly a cubic foot; a slide is now withdrawn at the bottom of the hopper, and the powder allowed to run into the box in a continuous even stream until it is piled up; the hopper is then removed, and the powder struck off with a straight edge, level with the top of the box. The weight is now carefully taken, that of the latter being subtracted; should this not amount to 55 lbs. it is rejected, as not being of sufficient density.*

Fourthly, samples are taken from every barrel and lot for the firing proof.

Firing Proof.—An average of nine rounds of sample Waltham Abbey powder is taken, three rounds being respectively fired at the beginning, middle, and end of the proof, from the same kind of mortar before mentioned, with a charge of 2 oz.; an average of three rounds of each lot of the merchants' powder is also taken; should it fall short by more than 1 in 20, it is rejected.

Fifthly, to ascertain if any residuum or ash is left after ignition, about half an ounce is burned on a clean glass plate and fired with a hot iron. The explosion should be sharp, and produce a sudden concussion in the air; and the force and power of this concussion should be judged by that of known good quality; few sparks should fly off, nor should white beads or globules appear, as it would be a sure indication, as we have explained before, of insufficient incorporation. It is also subjected to a second proof.

Second Proof.—A sample of 1 lb. from each lot, carefully weighed up, and a similar sample of the comparison powder, is exposed for three weeks in a box perforated with holes (called a damp chest) to the action of the atmosphere. This box is placed under cover, so that it is sheltered from the wet, but that the moisture can get to it; if, at the end of this time, there is a greater proportion of difference in range between them than one-twentieth, it is rejected; the pounds are also very carefully weighed up again, to ascertain the comparative absorption of moisture. This is called the hygrometric test.

The saltpetre is also subjected to chemical analysis, both as to its quality and proportion, in the following way:—

First, as to its Purity. About a quarter of an ounce is pounded in a mortar with distilled water; this is put into a test-tube, and boiled by a spirit-lamp. The solution is then filtered, a few drops of nitric acid and nitrate of silver are added; if cloudiness appears, the saltpetre is impure in proportion to the quantity and dirtiness in the appearance of the precipitate.

Secondly, as to its Proportion. A hundred grains of powder, freed from moisture, and very accurately weighed, are put into a glass with sufficient distilled water to hold it in solution; this is boiled and filtered, the charcoal and sulphur being well washed until all saltpetre is dissolved; the solution is then evaporated to dryness, and the weight of the residue represents the percentage of nitre.

It may also be arrived at indirectly, after the filtration, by drying the filter containing the sulphur and charcoal, subtracting the weight of the filter, previously

* A description will be given, in one of the following pages, of an apparatus invented by Colonel Mallet and M. Bianchi to test the density of powder.

ascertained, thus getting their weight. The difference between this and the original weight of powder being the proportion of nitre.

APPARATUS FOR DETERMINING THE SPECIFIC GRAVITY OF POWDER.

The following is a description of the principles of an Apparatus called the "Densimètre à Mercure," which is used in the French Service, for determining the specific gravity of powder.

"Appareil de Messieurs le Colonel d'Artillerie Mallet et Barthélemy Bianchi, pour déterminer la Pesanteur Spécifique des Grains de la Poudre. Appareil adopté par l'Administration de la Guerre.

"Parmi les épreuves réglementaires qui servent à constater qu'une poudre est de bonne qualité se trouve la détermination de sa densité réelle. On est convenu d'appeler 'densité réelle' le rapport du poids de la poudre au volume de ses grains, tels qu'ils sont constitués avec leurs pores entr'eux. Généralement cette densité s'obtient par l'immersion d'un poids donné de poudre dans un liquide dont la densité est connue, et qui, remplirant complétement les interstices des grains, ne doit pas pénétrer dans leurs pores. C'est sur ce principe que reposent les instructions ministérielles du 5 Juin, 1835, sur les épreuves des poudres au moyen de l'immersion dans l'eau saturée de salpêtre. Mais l'expérience à démontré que cette méthode, simple et facile en apparence, exige des précautions minutieuses et délicates, dont l'oubli ou la négligence peuvent altérer les résultats de manière à faire ressortir des anomalies telles qu'il n'est plus possible d'avoir confiance dans un semblable procédé.

"Ces anomalies proviennent des changements de température qui peuvent soit occasionner un dépôt de salpêtre de l'eau saturée, soit dissoudre une partie de salpêtre de la poudre; elles proviennent aussi de la tendance de l'eau à pénétrer dans les grains de la poudre.

"Pour obvier à ces inconvénients on a proposé l'emploi d'autres liquides, tels que l'essence de térébenthine, l'alcool, l'huile, etc., enfin le mercure, pour y faire l'immersion de la poudre. Le mercure seul a paru propre à conduire à la solution du problème; aussi c'est dans cette direction que des recherches ont été faites par des Commissaires et Inspecteurs des Poudres, des officiers attachés à la direction centrale des Poudres et Salpêtre, et que divers appareils ont été successivement proposés et soumis à un examen approfondi par une commission déléguée par Mons. le Ministre de la Guerre. Depuis 1837, jusqu'à ce jour, aucun des appareils proposés n'a résolu la question d'une manière assez satisfaisante et ont été successivement rejeté.

"Enfin Messieurs le Colonel d'Artillerie Mallet et Barthélemy Bianchi, Ingénieur Mécanicien du Service de Poudre et Salpêtre, qui se sont occupé de cette question avec beaucoup de soin, ont proposé un appareil qui, après de nombreux épreuves et un examen rigoureux, a donné le résultat le plus satisfaisant, et a été adopté par Mons. le Ministre de la Guerre, qui en a ordonné l'emploi dans le service de poudre.

"*Principe de l'Appareil.*—Cet appareil est destiné à être d'abord pesé plein de mercure seul; puis, après y avoir introduit un poids donné de poudre et l'avoir de nouveau rempli de mercure mêlé à la poudre, la différence des deux poids est evidemment la même que la différence entre le poids du mercure déplacé et le poids de la poudre.

"Ainsi soit—

P = le poids du vase plein de mercure.

P′ = le poids du vase plein avec mélange de poudre et mercure.

A = le poids connu de la poudre.

B = le poids cherché du mercure déplacé par la poudre.

"On a

$$P - P' = B - A\text{; d'où } B = P - P' + A.$$

"Ainsi la différence des deux pesées de l'appareil augmenté du poids de la poudre, représente le poids du mercure déplacé. Ce dernier poids divisé par la densité du mercure (qui doit être déterminé *à priori*) donne le volume de ce mercure déplacé, volume égal à celui occupé dans le vase par les grains de la poudre.

"Soit D = la densité connue du mercure.

V = le volume de mercure déplacé, ou le volume occupé par la poudre.

$$V = \frac{B}{D}$$

"Soit D′ densité cherchée de la poudre—

$$D' = \frac{A}{V} = \frac{AD}{B} = \frac{AD}{P - P' + A}$$

"La densité réelle de la poudre est égale à la densité du mercure multipliée par le poids de la poudre, et divisée par la différence des deux pesées augmentée du poids de la poudre."

Major Mordecai has entered very fully into the subject of the Proof of Gunpowder, and his remarks relating to the eprouvette, balistic, and gun pendulum will be found very interesting and instructive.

REMARKS ON THE PROOF OF POWDER BY THE EPROUVETTES.

"By comparing the results of the proofs by the eprouvettes with those furnished by the cannon pendulum, it will appear that the eprouvettes are entirely useless as instruments for testing the relative projectile force of different kinds of powder, when employed in large charges in a cannon. Powders of little density, or of fine grain, which burn most rapidly, give the highest proof with the eprouvettes, whilst the reverse is nearly true with the cannon. Thus, all the eprouvettes concur in assigning the first rank among the cannon powders to the powder F, which is the lowest on the scale by the cannon; whilst the powder A, which is the strongest in the gun, is one of the weakest by the eprouvettes. Nor do these instruments assign any superiority to powder which is well incorporated, over powder, of the same kind in other respects, which has been very imperfectly worked; on the contrary, they all give results with the powder incorporated by fifteen minutes' work under the rollers, equal or superior to those furnished by the same powder worked ninety minutes.

"The only real use of these eprouvettes is to check and verify the uniformity of a current manufacture of powder, where a certain course of operations is intended to be regularly pursued, and where the strength, tested by means of any instrument, should therefore be uniform; but as a means of proving Gunpowder received (as it is in our service) from manufactories pursuing entirely different processes, these eprouvettes may be pronounced worse than useless, since they may lead to erroneous results. By the French mortar eprouvette, scarcely any of the powders which we have found to be the strongest in the cannon, could be received as having given the required proof range of 246 yards."

The results by these eprouvettes correspond generally with those given by the 8-inch mortar, with a charge of 12 oz., by the 1-pounder gun pendulum, and by the musket pendulum, in which, as in all cases where small quantities of powder are used, rapidity of inflammation is the most influential element of strength.

EXPERIMENTS WITH THE 1-POUNDER GUN PENDULUM.

"Having ascertained that there is no correspondence between the indications of the force of cannon powder which are furnished by the gun itself, and those given

by the eprouvettes in common use, and also that no accurate indication of the relative force of different kinds of powder can be expected from the use of blank charges, even with large quantities of powder, I determined to try whether such an indication would be furnished by firing with balls from a gun of so small a calibre that its use would be attended with little difficulty or expense, and that the apparatus might even be susceptible of removal, if necessary, from place to place. For this purpose, I constructed a pendulum apparatus for a 1-pounder gun, to be fired with balls, with a charge of a quarter of a pound; the velocity of the ball to be computed from the recoil of the gun pendulum alone, in order to dispense with the costly and slow process of using the balistic pendulum.

"The results of the experiments with this pendulum are exhibited in the following table:—

Charge of Powder ¼ lb.; Windage of Ball 0·0475 inch.

Kind of Powder.	Initial Velocity of Ball.	Relative Force of Powder.	Kind of Powder.	Initial Velocity of Ball.	Relative Force of Powder.
A.	1407 feet	843	F.	1490 feet	890
A. 1	1370	821	F. 1	1459	875
A. 3	1467	880	F. 0	1476	885
A. 0	1463	877	G. 1	1406	843
A. 4	1574	944	G. 6	1668	1000
B.	1446	866			
B. 1	1381	828	K. 1. r.	1392	835
B. 3	1481	888	K. 1. g.	1366	819
C.	1452	870	R. 15	1460	875
D.	1376	825	R. 90	1502	900
E.	1161	692	X. p.	1489	893
E. 1	1110	665	X. p. 4	1534	919
E. 3	1263	757	X. p. 5	1635	980
E. 5	1429	857			

"From these results, it appears that the indications given by the 1-pounder gun, with respect to the relative force of different kinds of powder, conform much more nearly to those of the eprouvettes and the musket, in which small charges are used, than to those of the cannon with large charges. Thus, again, the powder F, which is among the weakest of the cannon powders in the 24-pounder gun, occupies nearly the highest rank in the 1-pounder gun; and the powder A, which is the strongest of all the cannon powders in the former gun, stands almost at the foot of the list in point of strength when tried by the latter; a similar remark may be made with respect to the powders D and K. In short, it appears that low density and fineness of grain, which are the qualities most favourable to the quickness of powder, exercise, in general, the greatest influence on the force of small charges; whilst, in large charges (unless the powder is excessively dense, as the sample E), the slower development of force, which would be caused by the less rapid combustion of the coarse grains of dense powder, seems to be more than compensated by the greater intensity of the flame produced by such powder; so that, in the combustion of large charges, the whole force of the powder is actually developed in a smaller compass, and therefore with greater effect, when the powder is dense."

This remark may be illustrated by a comparison of the initial velocities of balls

fired with similar charges from a large and a small gun, of nearly the same relative length of bore; thus, with a charge of one-fourth the weight of the ball, we have

With Powder A.

In the 24-pounder gun, a velocity of	1702 feet.
In the 1-pounder gun	1407
Difference	295

With Powder F.

In the 24-pounder gun, a velocity of	1552 feet.
In the 1-pounder gun	1470
Difference	82

The following conclusion with regard to the proof of Gunpowder has been arrived at by Major Mordecai:—

"The only reliable mode of proving the strength of Gunpowder is, to test it with service charges in the arms for which it is designed; for which purpose the balistic pendulums are perfectly adapted.

"Although the present tendency to the use of cannon of very large calibre would make the proof by means of a 32-pounder or 24-pounder gun more satisfactory than by using a piece of smaller calibre, it does not seem to be necessary to resort to those heavy guns for obtaining a correct indication of the relative force of different kinds of powder. We have seen, indeed, that such an indication is not given by a 1-pounder gun; but the experiments at Metz have shown that the 12-pounder gun classes the powders in the same order of strength as the 24-pounder; and further experiments may, perhaps, prove that a long gun of yet smaller calibre, a 9-pounder or a 6-pounder, will give corresponding results. As the use of the large balistic pendulum is difficult, slow, and expensive, and as the indications furnished by the recoil of the cannon pendulum correspond with those given by the balistic pendulum, I should propose, for the usual proof of Gunpowder, to make use of the cannon pendulum alone, employing a gun of the smallest calibre which will give correct results, and firing the balls into a bank of earth, which would not make them unfit for ordinary service.

"An apparatus of this kind would not be costly, and might therefore be erected at several of the arsenals, where powder may be conveniently received for inspection; the 24-pounder pendulum at Washington Arsenal being used occasionally for verification.

"In the 24-pounder gun, new cannon powder should give, with a charge of one-fourth, an initial velocity of not less than 1600 feet to a ball of medium weight and windage.

"For the proof of powder for small arms, the small balistic pendulum is a simple, convenient, and accurate instrument. The cost of the apparatus might be very much reduced, without impairing the accuracy of the results, by dispensing, in most cases, with the musket pendulum, which is the most costly part of it, and simply firing the ball into the balistic pendulum block, from a barrel set in a permanent frame.

"The common eprouvettes are of no value as instruments for determining the relative force of different kinds of Gunpowder."

OF THE SIZE OF GRAIN FOR GUNPOWDER.

With regard to the particular size of grain for Gunpowder, I am confident great

improvements might be made, both in obtaining greater regularity of effect and propelling force, by the adoption of a more uniform even grain. There are at present half-a-dozen different sizes in our cannon and musket powder; and I think it stands to reason, that the more equal the size, the more uniform will be the ignition of all the grains, and consequently the effect of the same charges will be much more regular.

I have made many experiments on a small scale, all of which go to prove the correctness of this assertion; they however require to be made with service charges, to decide the particular size that would be most advantageous. Major Mordecai does not think any change is necessary in the grain for cannon powder; should however it not be deemed incompatible with the convenience of service to multiply the varieties of powder for special purposes, he considers that there would probably be an advantage in using very large-grained powder for 13-inch mortars and heavy sea-coast howitzers, where enormous charges are used; by this means, the strain on the gun would be diminished, and the velocity of the ball perhaps increased.

DAMAGED POWDER.

Gunpowder that may have become too much damaged in transport to re-dust, is often worked over again, in the same way as a dust charge, provided the nitre is found to be pure; should, however, the grains not be very much broken up, by reeling it for one hour and a half, it will be perfectly freed from dust, and its original appearance and glaze nearly restored.

Powder, also, that may have imbibed an undue amount of moisture from damp magazines or exposure, can be re-stoved and dusted, which partially restores it. It would however be advisable generally, to use this powder for bursting shells, or for blank ammunition salutes, etc. etc., as little dependence can be placed on its regularity of effect, and I consider it most desirable that the best powder should always be used for actual practice and service.

Extracting saltpetre from damaged powder.—However useless Gunpowder may have become as a propelling agent, whether arising from immersion in the sea, exposure to weather, or being dangerous to re-work or store in magazines, from grit, etc., having got amongst it, upwards of one-third, in fact nearly one-half its original value, can always be regained by the extraction of the saltpetre, 96·5 per cent. of which can generally be obtained by the following operation. Eight barrels, or 800 lbs., are put into a copper with from 200 to 240 gallons of water, and brought to the boil; the solution is then pumped out into troughs, and passed through double filters, in the same way as before described for refining saltpetre, and received into crystallizing cisterns, where it is agitated till the flour is formed; the charcoal and sulphur remain behind in the copper and filters, and are of no further service.

REMARKS ON THE MOST ADVANTAGEOUS SITE FOR A GUNPOWDER FACTORY, AND THE GENERAL POSITION AND CONSTRUCTION OF BUILDINGS CONNECTED THEREWITH.

In making a few remarks on the above subject, there are two or three points to be considered, of which, perhaps, the following are the chief:—

1. The safest and cheapest motive power for the machinery.
2. The conveyance of the powder from each stage of manufacture to the next.
3. The general safety of the buildings, in their construction and position with regard to each other.

Water seems at once to suggest itself as best calculated to fulfil some of these conditions, and the banks of a river or head where there is sufficient fall and water supply would undoubtedly be the most advantageous position, both as regards economy and safety, for a manufactory of this description. Such a position would also present great facilities for the conveyance of the powder from one stage of manufacture to another, rendering accident less likely; for the covered boats which are used for this purpose can be brought alongside each building to be loaded, and the powder transferred from one to the other without the risk that other means might entail.

They should be so situated that each process follows next in succession to the previous one, thereby preventing a great deal of unnecessary labour, besides lessening the likelihood of danger, from powder passing backwards and forwards in front of the various buildings. The magazine for the finished powder should be as far away as possible from the neighbourhood of the manufactory, and situated so as to be quite out of the way of farm buildings, or traffic of any sort.

All sheds or coverings of the machinery ought to be separated as much as possible, and every operation carried on in detached buildings, so that any explosion or fire in one should not affect the rest; this should be particularly attended to in the more dangerous part of the manufacture, such as granulating, pressing, and dusting, where large quantities of powder are generally going through these particular stages. Where space is limited, this object can, to a certain extent, be attained, by placing high traverses of earth or brick-work between each, and rows of poplar and other trees should be cultivated, and planted so as to intersect the buildings, being found materially to assist these artificial means.

The Incorporating Mills, where there is not more than from 40 to 50 lbs. working at a time, are found safe with merely a corrugated iron division between them, extending rather higher and wider than the mills themselves. As a general rule, the floors of all buildings are covered with leather tacked to the wood, copper nails being invariably used; all projections and ledges inside should be avoided as much as possible, as they harbour the powder dust which floats in the air.

Every precaution should be taken against accident by explosion or fire extending. In the Government Factory, engines are always kept with hose fixed, and everything ready for an emergency, some in floating barges, and others in sheds in different parts of the works, and the whole of the workmen are divided into detachments, and told off to their respective engines, each one having two foremen, who are responsible for its being kept in good working order, and who drill their detachments twice a month.

To prevent friction from grit getting on the floors, and that which might arise from nails in boots, no one is allowed to enter any building in those that have been worn out of doors, and leather slippers are provided to supply their place; in consequence of these precautions, very few accidents occur in this country, particularly those of a serious character; for the small explosions which do happen occasionally, are confined entirely to the incorporating process, a remedy for which, in some slight degree, I have pointed out in a former chapter.

In nearly all the private establishments abroad that I have visited, there appears to be a total neglect of any of the above precautions; all the processes are carried on in adjoining buildings, some in rooms one above another. Grit, sand, and nails in boots never seem to be thought of; and in a manufactory in Prussia, where I proceeded to inspect some powder for the British Government, the examining house or magazine, where there were upwards of 500 barrels collected, was merely a slight wooden building close to the stamping mills, powder in it being so thick on the floor that it crumpled under one's feet like frozen snow. One manufacturer told me he had once an explosion that blew up a great part of his factory, the effect of which

was visible, though many years had elapsed; the same unconcern however appears to prevail, and it can only be ascribed to the interference of a merciful Providence that these accidents are not of more frequent occurrence.

OBSERVATIONS ON THE MANUFACTURE OF GUNPOWDER ON THE CONTINENT.

It is not my intention to enter into any detail of the method employed on the Continent for the production of Gunpowder; but it may not be uninteresting to have a slight knowledge of it, particularly as it will show the advantage of our own plan of manufacture, producing as it does a powder acknowledged by all to be of the best quality, in durability, strength, and equality of range.

The proportions of the three ingredients vary slightly all over the Continent, being as follows:—

	Saltpetre.	Charcoal.	Sulphur.
France ... Belgium ...	75	12·5	12·5
Russia	73·78	13·59	12·63
Prussia	75	13·5	11·5
Austria	75·5	13·2	11·3
Spain	76·47	10·78	12·75
United States ...	76	14	10

PRODUCTION AND PURIFICATION OF THE INGREDIENTS.

The nitre is purified in a similar way to the new method employed at Waltham Abbey, though it is seldom obtained with so faint a trace of chlorides, owing probably to its being of an inferior quality, and of higher refraction when it is imported.

The sulphur is supplied to the manufactories in the form of roll sulphur, from Marseilles and Bordeaux, where there are very large refineries.

The charcoal is prepared from dogwood, alder, willow, hazel, and poplar, sometimes in pits, and occasionally in cylinders, as at Waltham Abbey; at Wetteren, and in some parts of France, it is distilled by the action of steam. The "charbon roux," taking its name from its brownish-red tinge, from being only partially burned, was used formerly more than now, as the powder made from it was found to injure and exert very pernicious effects upon fire-arms.

PULVERIZING AND MIXING THE INGREDIENTS.

The ingredients are generally pulverized in copper drums capable of holding 224 kilogrammes: part of the charcoal is mixed with the sulphur, and part of the sulphur with the saltpetre; they are then put into separate drums, which revolve about twenty-five times per minute for three hours, and in which are about 500 gun-metal or bronze balls the size of good large marbles: the ingredients are brought to the most minute state of division by these means, and are then mixed altogether for one hour in similar drums covered with leather, containing wooden balls.

INCORPORATING PROCESS.

The fine powder thus obtained is sometimes merely moistened, so as to form a stiff paste, and passed through rollers, the cake formed being dried and granulated. The incorporating cylinders are used occasionally, but the more usual plan adopted on the Continent to effect this operation is the stamping-mill, which requires a short description. It is nothing more nor less than the pestle-and-mortar principle, each mill

consisting of from six to twelve bronze or wooden mortars bedded in the floor of the building; they are the shape of the frustum of a cone, the mouth being much narrower than the base; the pestles, or stampers as they are called, are made of wood, shod with either very hard wood or bronze, on which project wooden teeth about twelve inches long; a vertical movement is imparted to them by a shaft worked by the water-wheel having similar teeth attached; in its revolution it raises the stamper about eighteen inches, which falls again as the projection is disengaged, twenty-five times in a minute. This operation is carried on for twelve hours, during which period the charge (about 15 lbs.) is moistened at intervals, and routed up with a copper-shod spud; at the end of this time the cake is taken out, and left to dry and harden; it seldom receives any pressure—although, in some manufactories, presses are being erected.

GRANULATING.

The cake is then granulated in sets of sieves fitting one into the other, having perforated zinc bottoms of different degrees of fineness, which are suspended from the ceiling of the room by ropes, an ash spring being attached to each box holding the sieves; the cake is put into the uppermost one with some gun-metal balls, and shaken backwards and forwards, which motion the spring facilitates; it is thus broken up into different-sized grains, which are separated by passing through the several meshes.

The grain formed is then dusted in bags or shaking-frames covered with canvas, and then glazed in barrels.

STOVING, OR DRYING.

In summer, the process of drying is often performed in the sun, and in winter by the steam stove, in the following way. The powder is spread about three or four inches thick on a large canvas tray, under which is an arrangement of pipes, which convey the hot air forced by a fan through a cylinder heated by steam: it is considered to be sufficiently dried in from three to four hours, during which time it is occasionally raked about. In some manufactories it undergoes a further operation of being dusted, and is then barrelled up for use. Generally the great failing in the foreign manufacture is the neglect of the principal stage of the fabrication, viz. incorporation; with the old stamping-mill, it is quite impossible that the process can be carried out to the necessary extent. The Continental powder is usually very soft in its grain, dusty, and quickly absorbs moisture from the atmosphere; its density is below the English powder, on account of its never being subjected to pressure; consequently it is not so durable, and forms a good deal of dust in transport; a great amount of residue is generally left in the gun, and its strength, as a propelling agent, is far inferior to our powders. On being flashed on a glass plate, instead of producing a sudden concussion, like the sharp rap of a hammer, it burns more like composition, throwing off a quantity of sparks.

I have tried many experiments with all kinds of foreign powder, and find invariably, if the ingredients are pure, that, on subjecting it to an hour-and-a-half's incorporation, and passing it through the remaining different processes,—in fact remanufacturing it,—that its range will be increased by from eighty to one hundred feet, its appearance and goodness in all respects equalling the Waltham Abbey powder, showing clearly the advantage of our system.

ON THE PURCHASE AND REFRACTION OF SALTPETRE.

We have seen that saltpetre, in its grough state as it is imported, is combined with different deliquescent salts, some samples being more impure than others; it becomes

therefore necessary that there should be some means of guiding the purchaser in going into the market, in order that he may obtain the proper proportion of the pure material for the price paid; the difference between the original weight of a certain bulk and that which is left after refining being termed the refraction.

In the trade, the allowed refraction is 5 lbs. per cwt.,—that is to say, if saltpetre was at thirty shillings per cwt., and a purchaser wished to buy some at five per cwt. refraction, thirty shillings would have to be paid; but, on the other hand, if the refraction was below five per cwt., more than this sum would have to be paid, as a greater proportion of pure nitre would be obtained in the process of refining, making it consequently more valuable; and if above five per cwt., for the same reason, less would be paid, being of an inferior description.

To make the method of purchasing perfectly clear, I will annex a table of five tons refracted saltpetre from 1 to 15 lbs. per cwt., and a broker's invoice: from this it will appear that, according as the refraction is above or below the standard five, so must the difference be subtracted from or added to the gross weight, to arrive at the quantity to be paid for; tare, etc., being taken into due consideration.

SCALE FOR FIVE TONS REFRACTED SALTPETRE, FROM ONE TO FIFTEEN POUNDS PER CWT.

	Cwt.		qr.		lb.
1 ...	103	:	2	:	27
2 ...	102	:	3	:	6
3 ...	101	:	3	:	13
4 ...	100	:	3	:	21
5 ...	100	:	0	:	0
6 ...	99	:	0	:	7*
7 ...	98	:	0	:	15
8 ...	97	:	0	:	22
9 ...	96	:	1	:	1
10 ...	95	:	1	:	9
11 ...	94	:	1	:	16
12 ...	93	:	1	:	23
13 ...	92	:	2	:	3
14* ...	91	:	2	:	10
15 ...	90	:	2	:	17

Illustration, at the Refraction of 6 lbs. per Cwt.

112 : 100 : 112
5 6

107 106
100

107) 10600 (99 0 7*
963

970
963

7
112

107) 784 (7
749

35

BROKER'S INVOICE, AT THE REFRACTION OF 2¾ PER CWT.

	Cwt.	qr.	lb.
232 bags, gross weight ...	398	2	26
Tare 7 lbs. per bag, draft 1 lb. per bag	16	2	8
	382	0	18
Add the refraction of 2¾* per cwt.....	9	3	8
	391	3	26

232
7

	Cwt.	qr.	lb.
1624 lbs.....	14	2	0
232 lbs.....	2	0	8
	16	2	8

	£	s.	d.
at 40s. per cwt.	783	19	3
Brokerage 1 per cent.....	7	16	9
	£791	16	0

* It is called 2¾, but it is really the difference between 2¾ and 5, or 2⅝ per cwt.

INVOICE, AT THE REFRACTION OF $5\frac{3}{4}$ PER CWT.

	Cwt.	qr.	lb.		Cwt.	qr.	lb.
240 bags, gross weight ...	348	3	21	240			
Tare 9 lbs. per bag, draft 1 lb. per bag	21	1	20	9			
				2160 lbs.	19	1	4
	327	2	1	240 lbs.	2	0	16
Deduct the refraction of $5\frac{3}{4}$ lbs. per cwt.*	2	1	5		21	1	20
	325	0	24		£	s.	d.
				at 38s. per cwt.	617	18	1
				Brokerage 1 per cent.	6	3	6
					£624	1	7

The means usually adopted by merchants to test for the refraction is—by melting a portion in a small mould, breaking the cake, and examining the fracture. Should it present a fibrous, radiated appearance, without any small lumps, it is considered to be of low refraction; on the contrary, if these appear, it indicates the presence of salts; it requires however a practised hand to form any correct judgment by this method. Brokers and merchants, who are in the habit of examining it, can judge pretty accurately of its purity by the colour, size of its crystals, and general appearance.

Gay-Lussac's method of examining nitre consists in mixing about twenty grains (accurately weighed) of the dried specimen, with about ten grains of charcoal powder, and eighty grains of chloride of sodium: this mixture is introduced by small portions into an iron crucible heated to redness; the fused mass is dissolved in water, the solution coloured with litmus, and dilute sulphuric acid of known strength added from a graduated glass until a slight excess has been employed, which is known by the peculiar bright-red tint assumed by the solution. The number of measures of acid employed is then observed, and the amount of nitrate of potash to which they correspond, calculated. Forty parts (1 eq.) of sulphuric acid (SO_3) correspond to 101 parts (1 eq.) of nitrate of potash, as may be seen by the following equation, which exhibits the action of the carbon upon the nitrate of potash:—

$$2\,(KO, NO_5) + C_5 = 2\,(KO, CO_2) + N_2 + 3\,CO_2;$$

where it will be seen that every equivalent of nitrate of potash produces an equivalent of carbonate, which requires also one equivalent of sulphuric acid for its neutralization. The chloride of sodium is merely added to the mixture to moderate the violence of the deflagration.

A fallacious result will be obtained by this method, if the specimen examined contain sulphates, as they are reduced to sulphides by fusion with charcoal; these being decomposed by sulphuric acid (with disengagement of hydrosulphuric acid) their presence will involve the use of an excess of the test acid, and a consequent excess in the calculated percentage of nitre. If therefore hydrosulphuric acid is detected on the first addition of acid to the solution of the fused mass, recourse must be had to some one of the other methods.

ANALYSIS OF GUNPOWDER.

In a former part of this Article, under the head of "Proof of Merchants' Powder," I have described shortly the method of determining the proportion of nitre in samples of Gunpowder. To ascertain the amount of the other two ingredients however

* Which is really $\frac{3}{4}$ per cwt.

requires some delicate manipulation; and as it may interest some who may be chemically inclined, to try samples of powder, I will transcribe Abel and Bloxam's method, from page 678 of their excellent work, 'Handbook of Chemistry,' in order that those who have not the advantage of this book may be able to subject Gunpowder to chemical analysis.

"1. *Determination of Moisture.*—About twenty grains of the powder, very finely pulverized, are exposed over sulphuric acid, *in vacuo*, until a constant weight is obtained.

"For ordinary purposes, the moisture may be determined by exposing the powder to the temperature of the water-oven, until it ceases to lose weight. A slight excess is generally obtained by this method, since a small portion of the sulphur in the powder is expelled, together with the moisture.

"2. *Determination of Nitre.*—The dried powder is transferred to a small beaker, in which it is drenched with about three ounces of hot water, and allowed to digest for some time upon a sand-bath at a moderate heat. It is then thrown upon a filter of known weight, previously moistened, and is washed with hot water until a drop of the filtrate, which must be carefully collected, leaves no residue when evaporated upon platinum foil. The filter and residue are then dried in the water-oven (or, still better, *in vacuo*) until their weight is constant. The difference in weight between the residue (*minus* the weight of the filter) and the powder employed, will represent the amount of nitre.

"To control this result, the filtrate and washings, obtained as above directed, are carefully concentrated in a porcelain dish at a moderate heat upon a sand or air-bath, and afterwards transferred to a weighed platinum (or porcelain) capsule, and evaporated to dryness on a water-bath; the residue is then exposed to a temperature of 300° Fahr. (149° Cent.) in an air-bath, until it ceases to lose weight. The quantity of nitre is thus determined directly.

"3. *Determination of Sulphur.*—This ingredient may either be determined directly, or by the loss of weight sustained by dry powder upon its removal.

"Direct Determination.—*α.* About twenty grains of the dried powder are mixed with an equal weight of pure carbonate of soda (or of potash), about twenty grains of nitre and eighty grains of pure chloride of sodium are then added, the whole intimately mixed, and then submitted to fusion in a platinum crucible, the operation being conducted, and the sulphuric acid determined in the fused mass, in the manner directed at p. 653 of the Handbook.

"*β.* A tube of hard glass provided with two bulbs is accurately weighed; about twenty grains of dried powder are introduced into one of the bulbs, and the weight of the tube and powder noted; the difference between the two weights will represent the amount of powder employed. The extremity of the tube nearest to the bulb containing the powder is then attached to an apparatus in which dry hydrogen is disengaged. A slow current of gas is allowed to pass through the tube; as soon as the atmospheric air is completely expelled, the bulb containing the powder is moderately heated by means of a spirit-lamp, when the sulphur will vaporize, and pass over into the second bulb, where it will again condense; the space of tube between the two bulbs must be warmed with the spirit-lamp from time to time, to prevent any sulphur from condensing there. When no more sulphur is expelled from the powder, which is finally exposed to a temperature approaching dull redness, the tube is allowed to become nearly cool; it is then carefully cut with a very sharp file between the two bulbs, and each part is afterwards weighed, cleaned out, and re-weighed. The amount of sulphur found in the second bulb should correspond, within the limits of error, 0·5 per cent. loss, to the difference between the first and the final weight of the powder.

"A slight loss of sulphur by this method is unavoidable, small portions being carried off mechanically by the current of hydrogen, if ever so slow; while a small quantity is also converted into hydrosulphuric acid.

"By adopting the following modification of this method, very accurate results may however be arrived at:—

"Instead of a tube with two bulbs, one of rather wider bore, about eight inches in length, is employed, provided with only one bulb, at about two inches from one extremity of the tube. A small plug of dry asbestos having been introduced into the long arm of the tube, about half-an-inch distant from the bulb, the former is filled with thin filaments of dry bright copper, or of the finely-divided metal reduced from the oxide by hydrogen. The tube is then accurately weighed, the dried powder, from which the nitre has been removed, introduced into the bulb, and the weight again ascertained—the difference will give the amount of powder employed. The operation is then conducted as before. with this difference, that the copper is first raised to a red heat, and maintained at that temperature, before the sulphur is expelled from the powder. The sulphur-vapour, coming in contact with the heated metal, will at once combine with it, and no loss whatever is sustained. When the operation is completed, and the tube is cooled down sufficiently to be handled without inconvenience, it is carefully cut between the asbestos plug and the bulb; the latter, containing the charcoal, is then placed on the balance while warm, and rapidly weighed; the loss of weight expresses the amount of sulphur, which may also be directly inferred from the increase of weight of the tube containing the copper.

"Indirect Determination.—A weighed portion of the dry residue of carbon and sulphur left on extracting the powder with water, is introduced into a small flask, and boiled for some time with a solution of sulphide of potassium or of sodium, or of sulphite of potassa or soda, until the whole of the sulphur is removed. The carbon is then collected upon a weighed filter, well washed, dried in a water-oven, and weighed; the difference between this weight and that of the original residue of carbon and sulphur indicates the amount of the latter, which must now be calculated for so much of this residue as would be furnished by 100 parts of gunpowder; the result is the percentage of sulphur.

"The alkaline sulphides or sulphites employed to dissolve the sulphur must be perfectly free from caustic alkali, since the latter is capable of attacking charcoal which has not been very thoroughly charred. A mixture of the bisulphide of carbon and alcohol may also be employed to extract the sulphur.

"The results obtained by the indirect method are invariably too low, since the extraction of the sulphur is never complete.

"4. *Determination of Carbon.*—The amount of this constituent will have been ascertained by difference, and controlled by direct weighing in the preceding determinations. It is sometimes necessary, especially when *charbon roux* has been employed, to determine the amount of hydrogen contained in the charcoal; this is effected by burning a weighed quantity with oxide of copper in the manner to be described in a future part of the work, under the head of Organic Analysis."

H.

HEAT.*—Heat, in the ordinary application of the word, signifies, or rather implies, the sensation experienced upon touching a body hotter, or of a higher temperature, than the part or parts which we bring into contact with it: in another sense, it is used to express the cause of that sensation. To avoid any ambiguity that may arise from this double use of the same expression, it is usual and proper to employ the word *Caloric* to signify the principle or cause of the sensation of heat. On touching a hot body, caloric passes from it, and excites the feeling of warmth: when we touch a body having a lower temperature than our hand, caloric passes from the hand to it, and thus arises the sensation of cold.

Caloric is usually treated of as if it were a material substance; but, like light and electricity, its true nature has yet to be determined.

COMMUNICATION OF CALORIC.

Caloric passes through different bodies with different degrees of velocity. This has led to the division of bodies into *conductors* and *non-conductors* of caloric: the former includes such bodies as metals, which allow caloric to pass freely through their substance; and the latter comprises those that do not give an easy passage to it, such as stones, glass, wood, charcoal, etc.

Table of the relative Conducting power of different Bodies.

Gold	1000	Platinum	981
Silver	973	Copper	898
Iron	374	Zinc	363
Tin	304	Lead	180
Marble	24	Porcelain	12·2
Fire-brick	11	Fire-clay	11·4

With Water as the Standard.

Water	10	Elm	32
Pine	39	Ash	31
Lime	39	Apple	28
Oak	33	Ebony	22

Relative Conducting Power of different Substances compared with each other.

Hare's fur	1·315	Cotton	1·046
Eider-down	1·305	Lint	1·032
Beaver's fur	1·296	Charcoal	·937
Raw silk	1·284	Ashes (wood)	·927
Wool	1·118	Sewing silk	·917
Lamp-black	1·117	Air	·576

Relative Conducting Power of Fluids.

Mercury	1·000	Proof Spirit	·312
Water	·357	Alcohol (pure)	·232

* Compiled by Colonel Portlock.

RADIATION OF CALORIC.

When heated bodies are exposed to the air, they lose portions of their heat, by projection in right lines into space, from all parts of their surface.

Bodies which radiate heat best, absorb it best.

Radiation is affected by the nature of the surface of the body; thus, black and rough surfaces radiate and absorb more heat than light and polished surfaces.

Table of the Radiating Power of different Bodies.

Water	100	Blackened tin	100
Lamp-black	100	Clean „	12
Writing paper	100	Scraped „	16
Glass	90	Ice	85
Indian Ink	88	Mercury	20
Bright lead	19	Polished iron	15
Silver	12	Copper	12

Reflection of Caloric differs from Radiation, as the caloric is in this case reflected from the surface without entering the substance of the body: hence the body which radiates, and consequently absorbs most caloric, reflects the least, and *vice versâ*.

SPECIFIC CALORIC.

Specific Caloric is that which is absorbed by different bodies of equal weights or volumes in attaining an equal temperature, based upon the law, acknowledged as universal, *that similar quantities of different bodies require unequal quantities of caloric, to maintain any given temperature.* Dr. Black termed this, *Capacity* for caloric; but as this term was supposed to be suggested by the idea that the caloric present in any substance is contained in its pores, and, consequently, the capacities of bodies for caloric would be inversely as their densities; and such not being the case, this word is apt to give an incorrect notion, unless it is remembered that it is but an expression of fact, and not of cause; and to avoid error, the word specific was proposed, and is now very generally adopted.

It is important to know the relative specific caloric of bodies. The most convenient method of discovering it is by mixing different substances together at different temperatures, and noting the temperature of the mixture; and by experiments it appears that the same quantity of caloric imparts twice as high a temperature to mercury as to an equal quantity of water; thus, when water at 100° and mercury at 40° are mixed together, the mixture will be at 80°, the 20° lost by the water causing a rise of 40° in the mercury; and when weights are substituted for measures, the fact is strikingly illustrated; for instance, on mixing a pound of mercury at 40° with a pound of water at 160°, a thermometer placed in it will stand at 155°. Thus it appears that the same quantity of caloric imparts twice as high a temperature to mercury as to an equal volume of water, and that the heat which gives 5° to water will raise an equal weight of mercury 115°, being the ratio of 1 to 23. Hence, if equal quantities of caloric be added to equal weights of water and mercury, their temperatures will be expressed in relation to each other by the numbers 1 and 23; or, in order to increase the temperature of equal weights of those substances to the same extent, the water will require 23 times as much caloric as the mercury.

The rule for finding by calculation, combined with experiment, the relative capacities of different bodies, is this:

Multiply the weight of each body by the number of degrees lost or gained by the mixture, and the capacities of the bodies will be inversely as the products.

Or, if the bodies be mingled in unequal quantities, the capacities of the bodies

will be reciprocally as the quantities of matter, multiplied into their respective changes of temperature.

The general facts respecting specific caloric are as follows :—

1. Every substance has a specific heat peculiar to itself, whence a change of composition will be attended by a change of capacity for caloric.

2. The specific heat of a body varies with its form. A solid has a less capacity for caloric than the same substance when in the state of a liquid; the specific heat of water, for instance, being 9 in the solid state, and 10 in the liquid.

3. The specific heat of equal weights of the same gas increases as the density decreases; the exact rate of increase is not known, but the ratio is less rapid than the diminution in density,

4. Change of capacity for caloric always occasions a change of temperature. Increase in the former is attended by diminution of the latter; a portion of the sensible heat becoming absorbed and latent, and *vice versâ*.

Tables of the Specific Heat of various Substances.

1. Air taken as unity.

	Equal Volumes.	Equal Weights.
Air	1·000	1·000
Hydrogen	·903	12·340
Carbonic acid	1·258	·828
Oxygen	·976	·884
Olefiant gas	1·553	1·576

The specific heat of the foregoing, compared with that of an equal quantity of water:—

Water	1·0000	Hydrogen	3·293
Air	·2669	Carbonic acid	·221
Oxygen	·2361	Olefiant gas	·420

2. Water taken as unity, the weights equal.

Bismuth	·0288	Tellurium	·0912
Lead	·0293	Copper	·0949
Gold	·0298	Nickel	·1035
Platinum	·0314	Iron	·1100
Tin	·0514	Cobalt	·1498
Silver	·0557	Sulphur	·1880
Zinc	·0927	Mercury	·0330

ILLUSTRATION.—If 1 lb. of coal will heat 1 lb. of water to 100°, ·033 = $\frac{1}{30}$ of a lb. will heat 1 lb. of mercury to 100°.

The term *Capacity* for heat means the relative powers of bodies in receiving and retaining heat, in being raised to any given temperature; while *Specific* applies to the actual quantity of heat so received and retained.

When a body has its density increased, its capacity for heat is diminished. The rapid reduction of air to $\frac{1}{5}$ of its volume evolves heat sufficient to inflame tinder.

Table showing the relative Capacity for Heat of various Bodies.

	Equal Weights.	Equal Vol.		Equal Weights.	Equal Vol.
Glass	·187	·448	Silver	·082	·833
Iron	·126	·993	Tin	·060	—
Brass	·116	·971	Gold	·050	·966
Copper	·114	1·027	Lead	·043	·487
Zinc	·102	—	Water	·100	·100

Latent Caloric is that which is insensible to the touch, or incapable of being detected by the thermometer. The quantity of heat necessary to enable ice to assume the fluid state is equal to that which would raise the temperature of the same weight of water 140°; and an equal quantity of heat is set free from water when it assumes the solid form.

If $5\frac{1}{2}$ lbs. of water, at the temperature of 32°, be placed in a vessel communicating with another one (in which water is kept constantly boiling at the temperature of 212°), until the former reaches the temperature of this latter quantity, and be then weighed, it will be found to weigh $6\frac{1}{2}$ lbs., showing that 1 lb. of water has been received in the form of steam through the communication, and re-converted into water by the lower temperature in the vessel.

Now this pound of water, received in the form of steam, had, when in that form, a temperature of 212°. It is now converted into the liquid form, and still retains the same temperature of 212°; but it has caused $5\frac{1}{2}$ lbs. of water to rise from the temperature of 32° to 212°, and this without losing any temperature of itself. It follows, then, that in returning to the liquid state, it has parted with $5\frac{1}{2}$ times the number of degrees of temperature between 32° and 212°, which are equal 180°, and $180° \times 5\frac{1}{2} = 990°$. Now this heat was combined with the steam; but as it was then not sensible to a thermometer, it was called *Latent.*

It is manifest, then, that a pound of water, in passing from a liquid at 212° to steam at 212°, receives as much heat as would be sufficient to raise it through 990 thermometric degrees, if that heat, instead of becoming latent, had been *Sensible.*

The sum of the sensible and latent heat of steam is always the same at any one temperature; thus, $990° + 212° = 1202°$.

If to a pound of newly-fallen snow were added a pound of water at 172°, the snow would be melted, and 32° would be the resulting temperature, 138° of heat becoming latent in the melted snow.

Latent heat of various Substances.

Fluids.		Vapours.	
Ice	140°	Steam	990°
Sulphur	144	Vinegar	875
Lead	162	Ammonia	860
Bees'-wax	175	Alcohol	442
Zinc	493	Ether	302

Sensible Caloric is free and uncombined, passing from one substance to another, affecting the senses in its passage, determining the height of the thermometer, and giving rise to all the results which are attributed to this active principle.

To reduce the degrees of a Fahrenheit thermometer to those of Réaumur and of the centigrade; the Zero of the Réaumur scale being at the freezing point, and 80° *at the boiling point, whilst the zero of the centigrade is at the freezing point, and* 100° *at the boiling.*

FAHRENHEIT TO RÉAUMUR.

RULE.—Multiply the number of degrees above or below the freezing point by 4 and divide by 9.

Thus, $212° - 32 = 180 \times 4 = 720 \div 9 = 80$, *Ans.*

$+24° - 32 = -8 \times 4 = -32 \div 9 = -3{\cdot}5$, *Ans.*,

or 3·5 below zero.

FAHRENHEIT TO CENTIGRADE.

RULE.—Multiply the number of degrees above or below the freezing point by 5, and divide by 9.

Thus, $212° - 32 = 180 \times 5 = 900 \div 9 = 100$, *Ans.*

Or, multiply the degrees of Fahrenheit by ·444 for reducing them to Réaumur, and by ·555 for reducing them to centigrade.

Medium Heat of the Globe is placed at 50°; at the torrid zone, 75°; at moderate climates, 50°; near the polar regions, 36°.

The extremes of *natural heat* are from −70° to 120°; of *artificial heat*, from −91° to 36,000°.

EVAPORATION.

Evaporation produces cold, because caloric must be absorbed in the formation of vapour, a large quantity of it passing from a sensible to a latent state, the capacity for heat of the vapour formed being greater than that of the fluid from which it proceeds.

Evaporation proceeds only from the surface of the fluids, and therefore, *other things equal*, must depend upon the extent of surface exposed.

When a liquid is covered by a stratum of dry air, evaporation is rapid, even when the temperature is low.

CONGELATION AND LIQUEFACTION.

Water on freezing gives out 140° of heat. Water may be cooled to 20°. All solids absorb caloric when becoming fluid.

The particular quantity of caloric which is required to maintain a substance fluid is called its caloric of fluidity, or latent heat.

The caloric absorbed in liquefaction is given out again in freezing.

Fluids boil in vacuo *with* 124° *less of heat than when under the pressure of the atmosphere. On Mont Blanc, water boils at* 187°. This fact was ingeniously applied by Wollaston to the determination of altitudes by the temperature of the boiling point.

DISTILLATION.

Distillation is a double process, combining evaporation, or the formation of vapour, in the first instance; and in the second, condensation, or the reduction of that vapour to a liquid form. By this process the more readily vaporizable portions of bodies are separated from the more fixed, as alcohol from fermented liquors, water from saline solutions, mercury from amalgams. When the vapour is reduced to a solid form, as in the distillation of zinc, sulphur, etc., it is called sublimation. As the pressure of the atmosphere co-operates as a direct force in retaining bodies in their ordinary condition of solids or liquids, any diminution of that pressure must facilitate their assumption either of a liquid or gaseous form, and hence distillation *in vacuo* is much more rapid than it would be under ordinary circumstances; but as the vapour under diminished pressure has a greater capacity for caloric, there would be no ultimate saving of fuel by such an arrangement.

Table of Effects upon Bodies by Heat.

	Fahrenheit.
Cast iron, thoroughly smelted	2754°
Fine gold, melts	1983
Fine silver, melts	1850
Copper, melts	2160

	Fahrenheit.
Brass, melts	1900
Red heat, visible by day	1077
Iron, red-hot in twilight	884
Common fire	790
Iron, bright red in the dark	752
Zinc, melts	740
Quicksilver, boils	630
Linseed oil, boils	600
Lead, melts	594
Bismuth, melts	476
Tin, melts	421
Tin and bismuth, equal parts, melt	283
Tin 3 parts, bismuth 5, and lead 2, melt	212
Alcohol, boils	174
Ether, boils	98
Human blood (heat of)	98
Strong wines, freeze	20
Brandy, freezes	7
Mercury melts	−39

Wedgwood's zero is 1077° of Fahrenheit, and each of his degrees is equal to 130° of Fahrenheit.

Note.—Late experiments have shown the previous computations for extreme heats to be erroneous.

MISCELLANEOUS.

FRIGORIFIC MIXTURES.

Mixtures.	Thermometer falls, or degrees of cold produced.	Degrees of Fahrenheit.
Nitrate of ammonia 1 part Water 1 „	46°	From + 50° to + 4°
Phosphate of soda 9 parts Nitrate of ammonia 6 „ Dilute nitric acid 4 „	71°	From + 50° to − 21°
Sulphate of soda 8 „ Muriatic acid 5 „	50°	From + 50° to 0°
Snow 2 „ Muriate of lime 3 „	53°	From − 15° to − 68°
Snow 8 „ Dilute sulphuric acid 10 „	22°	From − 68° to − 90°
Snow 3 „ Potash 4 „	83°	From + 32° to − 51°

EXPANSION OF SOLIDS.

At 212°, the length of the bar at 32° considered as 1·0000000.

Glass	·0008545	Gold	·0014950
Platina	·0009542	Copper	·0017450
Cast iron	·0011112	Brass	·0019062
Steel	·0011899	Silver	·0020100
Marble	·0011041	Fire-brick	·0004928
Forged iron	·0012575	Lead	·0028436
Granite	·0007894	Zinc	·0029420

To find the expansion in surface or in volume, it must be remembered that each dimension of a solid experiences a similar proportional expansion.

Table of the Expansion of Air by Heat.—By MR. DALTON.

Fahrenheit.		Fahrenheit.		Fahrenheit.	
32°	1000	50°	1043	80°	1110
33	1002	55	1055	85	1121
34	1004	60	1066	90	1132
35	1007	65	1077	100	1152
40	1021	70	1089	200	1354
45	1032	75	1099	212	1376

EFFECTS OF HEAT.

Fahrenheit.	Wedgwood.	
−90°	—	Greatest cold ever produced.
−50	—	Natural cold at Hudson's Bay.
0	—	Snow and salt, equal parts.
+43	—	Phosphorus burns.
60° to 77	—	Vinous fermentation.
78	—	Acetous fermentation begins.
88	—	Acetification ends.
638	—	Lowest heat of ignition of iron in the dark.
800	—	Charcoal burns.
8490	57°	Working heat of plate glass.
14337	102	Stone ware, fired.
16807	124	Greatest heat of plate glass.
25127	185	Greatest heat observed.

MELTING POINT OF ALLOYS.

Lead 2 parts,	tin 3 parts,	bismuth 5 parts		melts at	212°
„ 1 „	„ 4 „	„ 5 „		melts at	246
	„ 1 „	„ 1 „		melts at	286
	„ 2 „	„ 1 „		melts at	336
Lead 2 parts,	tin 3 parts,			melts at	334
	„ 8 „	„ 1 „		melts at	392
„ 2 „	„ 1 „	common solder,		melts at	475
„ 1 „	„ 2 „	soft solder,		melts at	360

Boiling-points.—The boiling-point of water, from 27 to 31 inches of the mercurial column, varies 1·65° for every inch, being at 30 inches 212°; and on this variation, as before stated, is founded the apparatus of Dr. Wollaston, since modified with some improvements by the French, for determining altitudes.

COMPARATIVE HEAT FROM VARIOUS FUELS.

1 lb. of tolerably good coal will raise the temperature of 60 lbs. of water from 32° to 212°.

1 lb. of kiln or perfectly dried wood will effect the same on 35 lbs.

1 lb. of wood simply dried in the air „ „ 26 lbs.

1 lb. of charcoal „ „ 79 lbs.

Turf of good quality yields as much heat for equal weights as wood, and the heat

it gives out by radiation whilst burning has been considered even greater than that of wood.

PRACTICAL DISTRIBUTION OF HEAT.

The distribution of heat in warming buildings may be regulated on either of the following systems or principles :—

1. *By open Fire-places,* in which the air of the room is heated by radiation from the burning fuel. In this system, heating and ventilation are combined, as the smoke-flue continually draws away a large quantity of air, which must be replaced by the external air entering either by doors, windows, or apertures specially contrived for the purpose. As much of the air drawn off has been heated, but not dispersed through the rooms or buildings, there is a great loss of heat in every apparatus of this kind, which increases in proportion to the force of draught and size of the throat to the flue. To obtain the greatest effect from an open fire-place, the throat of the flue should be no larger than is absolutely necessary to maintain an efficient draught, and should be so placed as to keep the radiating flame as long as possible in view; or if it be made on the Sandham principle, immediately above and at the back of the fuel, the flame should pass behind a curved or inwardly-inclined metallic back, which would then become the radiating surface, as otherwise the loss of heat must be very great.

2. *By Stoves,* containing the fuel within them. The heat from iron stoves may be made very great, and they are therefore, when on good constructions, very efficient means of heating, were amount of heat alone to be considered; but as the quantity of air drawn off for the consumption of the fuel is comparatively small, and the air in contact with highly heated metal is much vitiated, they are inadequate as ventilators, and become injurious to respiration. Basins of water placed on such stoves, remove the sense of dryness, but do not restore its purity to the vitiated air. By substituting for metal less conductible materials, and increasing the quantity of matter to be heated, other forms of stoves are produced, which, by not heating the air in contact with them to so great a degree, are less objectionable, though as ventilators they are equally imperfect: the large German stoves are of this description.

3. *By Steam.*—The steam is on this principle carried by pipes through the buildings. If the temperature of the pipes falls below 212°, the steam is condensed, and, occupying as water only a very small portion of the pipes, their temperature rapidly decreases, and the change of temperature in the room is immediate. In keeping the temperature up to 212°, it is very difficult, the pipes being small, to avoid a dangerous augmentation of temperature, which may either lead to cracks of the pipes, or to accidents by inflaming substances in contact with them, and these are strong objections to this system. On this and on the following systems, ventilation must be considered apart from heating, though the combustion of the fuel may here, as in fire-places, or in stoves, be made the prime mover of that operation.

4. *By Hot Water,* direct.—In this system, pipes are carried from a boiler, first directly to the rooms to be heated, and then return to the boiler. The circulation of the hot water through these pipes produces the heat, and as a very moderate elevation of temperature is sufficient to produce an efficient circulation of the fluid, there is no necessity for raising the heat in the pipes beyond 200°, the required temperature in the rooms being secured by the length and size of the pipes. This is a very great advantage, as it removes all chance of danger from accidental combustion, and of vitiation of the air by over-heating. The precaution to be taken is, so to regulate the expansion-pipe and air-valve as to prevent any accumulation of air in elevated parts of the pipes, as the current would be stopped by its expansion and resistance.

5. *By Hot Water*, indirect.—Here the hot-water pipes pass through an air chamber, and the air thus heated is conducted by tubes or flues into the several chambers or rooms to be heated. This has an advantage in large military buildings, as the apparatus may be placed in a basement, and therefore, with the pipes, removed from the chance of injury.

6. *By Hot Water*, high pressure.—Here the expansion of the water by the expansion-tube is stopped, and the water is thereby allowed to attain a higher temperature than that of boiling water. Stronger, but smaller, pipes are here required; but as they are subject to accident from careless management, and become dangerous, like steam pipes, from accumulation of heat, the system is not to be recommended.

7. *By Hot Air.*—Here the air circulates round a stove or heater, and is then conducted by flues to the rooms; but as the air is vitiated in the same manner as by contact with common stoves, and may attain a dangerous elevation of temperature, the system is not equal to either 4 or 5.

The details of these methods will be given under "Warming and Ventilation of Buildings."—J. E. P.

HORSE—Powers of the.—Like all other animal powers, that of the horse may be applied in two ways; the first being that in which it is made to move forward, with or without a load; the second being that in which it is attached to a portion of machinery, upon which it either exercises an effort of traction or of pressure. This effort is subsequently transmitted to another portion of the machinery in immediate communication with the resistance. The *useful daily labour* of any animal power is that developed within 24 hours. Of course the duration of the effective effort only occupies a portion of the day, the remainder being necessarily occupied by the periods of repose or of refreshment.

The regularity and the moderation of the effort exerted daily has very great influence upon the preservation of the animals. Whatever may be the description of machine to which they may be attached, the labour must be regulated so as not to exceed the limits of their natural powers. These limits may be ascertained by observing the fatigue the animals suffer, and it may be specifically designated as the *daily fatigue.* But it is necessary to observe, that the daily fatigue of all animal powers differs within a very wide range, according to the manner in which the effort is applied; so that the effective dynamical efforts of such powers, in a day of 24 hours, can only be compared with one another when they are applied under similar circumstances and to the same description of work.

The effective daily power exerted by any agent consists of two parts; one, which is entirely destroyed by the agent in producing its own motion, and the other, which is transmitted to the resistance offered by the machinery. The latter portion is the only one susceptible of being expressed by numbers; and it has been demonstrated by numerous experiments that it varies in all cases according to the nature and duration of the effort, and according to the influence of the latter upon the organs of the animal,—whether a man, a horse, or an ox be considered.

In all investigations of the useful effect of animal power, it must be recollected that the pressure which any motive force exercises upon the different points by which it transmits its action to any part of the machine, multiplied by the velocity of those parts, is the expression, or measure, of the action of the motive power in the unit of time. The velocity is easily ascertained; the pressure requires the application of a description of machinery of the class known technically as the *dynamometer.*

Of the Speed of the Horse.—The greatest speed maintained by a horse, during the space of from 7 to 8 minutes, of which any authentic records exist, is about equal to 16·44 yards per second, or 986·40 yards per minute; it was on the occasion when 'Flying Childers' ran over the Beacon Course at Newmarket (7398 yards) in 7 minutes and 30 seconds. 'Firetail,' in 1772, ran one mile in 64 seconds, or at the rate of 27·2 yards, nearly, per second; but the greatest speed maintained by a horse carrying merely the rider, without load, for an hour, has not much exceeded twenty miles an hour, or about 9·8 yards per second. It has also been observed that a horse carried its rider only, over a road in the form of an 8 laid on its side, at the rate of about 13·4 yards per second, for a space of 211 seconds; and that when harnessed to a car it could maintain a speed of about 12 yards per second for about 133 seconds; but if the latter effort be maintained for an hour, it will very rarely equal $7\frac{1}{2}$ yards per second.

The greatest speed for a running horse may then, for a short distance, be taken at about	27	yards per second.
For a few minutes, at	16	„ „
For an hour	$9\frac{3}{4}$	„ „
The greatest speed when drawing a light car for a short distance, may be taken at	$13\frac{1}{3}$	„ „
For one hour it would be	$7\frac{1}{2}$	„ „
Cavalry horses generally make in a minute, at ordinary pace, 120 steps, and they cover	110	yards;
At a trot, 180 steps	220	„
At a gallop, 100 steps	352	„

From which it would appear that the length of the stride at the ordinary pace is about 0·917 yard, and that the velocity corresponds to about 1·84 yard per second; at a trot, the stride is about 1·23 yard, and the speed about 3·68 yards per second; and at a gallop, the stride is about 3·52 yards, with a speed of 5·87 yards per second. The length of the stride therefore increases with the speed, and this is accounted for by the fact that the horse, at higher velocities, leaps forward at the same time that he advances.

A good horse carrying a soldier of the baggage-train with his arms and accoutrements, supposed to weigh about 225 lbs., can travel, without over-exertion, 25 miles in a day of from 7 to 8 hours; his speed in this case would be between about 1·75 yard and 1·53 yard per second.

The weight of an average-sized horse is about from 8 to 12 cwt.

Of the Draught of the Horse.—For short distances and small speeds it is usual to make the load a horse is required to draw equal to one ton avoirdupois; but carriers rarely require their horses upon long stages to draw more than from 14 to 15 cwt.

The effort a superior draught-horse is able to exercise, at what is commonly called a dead pull, is considered to vary between 216 lbs. and 400 lbs.; the latter being the average force of the Norman breed of cart-horses, one of the finest in Europe. The road waggons in that country generally travel about 25 miles in eight hours upon a good horizontal road, and the horses rest during the remainder of the 24 hours. Under these circumstances the horses move at a speed of about 1·53 yard per second.

It is customary in England to calculate the effective draught of a horse moving at the rate of six miles an hour, as being only one-fourth of that which he exercises when moving the load from a state of rest. But M. Gueniveau ascertained that the diligence horses moving constantly at a trot, with a speed of $7\frac{1}{2}$ miles per hour, only lost $\frac{5}{14}$ of that power. He found that the horses upon which his observations were made exercised at that speed an effort equal to about 198 lbs., which is much in excess of our usual calculations, and may again be accounted for by the difference of

races. In our own country the tendency has been of late, in fact, to cultivate speed at the expense of the effective draught of the horse. The diligence horses experimented upon by M. Gueniveau travelled at the rate of 2·40 yards per second.

Taking, however, the effective draught of the carrier's horse at 400 lbs., and the distance generally travelled by him to be 25 mlles per day; and the effective draught of the slow coach horse at 198 lbs. for a mean distance of 24 miles; the dynamical actions will be expressed by the quantities 10,000 and 4752 respectively, or in the ratio of 100 : 47·52.

The Table given by Mr. Gordon to illustrate the effect of velocity upon the useful effort a horse can exert, shows very different results from those obtained by M. Gueniveau; and indeed the latter are so far in excess of the performances of the ordinary description of horses, that perhaps it may be safer to adopt Mr. Gordon's results. For the facility of comparison, the figures of his Table have been changed, by reducing them to proportions of the same unity; and the power of a horse drawing a load at a velocity of 3 miles per hour has been taken as the standard. It will be seen at once how very important an influence the velocity exercises upon the useful effect.

Table of proportionate loads to different velocities; the load drawn at the velocity of 3 *miles per hour being taken as unity.*

The load of a horse moving at	1	mile	per	hour	will be 1·26
,, ,,	2	miles	,,	,,	1·17
,, ,,	3	,,	,,	,,	1·00
,, ,,	4	,,	,,	,,	0·83
,, ,,	5	,,	,,	,,	0·69
,, ,,	6	,,	,,	,,	0·55
,, ,,	7	,,	,,	,,	0·45
,, ,,	8	,,	,,	,,	0·34
,, ,,	9	,,	,,	,,	0·23
,, ,,	10	,,	,,	,,	0·17
,, ,,	11	,,	,,	,,	0·07
,, ,,	12	,,	,,	,,	0·06
,, ,,	13	,,	,,	,,	0·028
,, ,,	14	,,	,,	,,	0·007
,, ,,	15	,,	,,	,,	0·000

The experiments recorded by M. Hachette appear to indicate that the average draught of horses was equal to 221 lbs. when applied to mills working pumps, or similar machinery. Upon roads, the useful action becomes modified by a great number of causes, whether arising from the condition of the road itself, from the state of the weather, or from the physical condition of the animal. Any general rule which may be laid down must therefore be considered as being only applicable within limits susceptible of considerable extension. Indeed, it must be evident that the nature of the materials used in the construction of the roads, and the various inclinations they may assume, must exercise great influence upon the useful action of the horses working upon them. The draught in winter also must naturally be more disadvantageous than that in summer; and it must be equally evident that a horse can exercise greater power in some states of health, and under certain conditions of excitement, than in, or under, others. From some experiments made with a view to ascertain the precise difference observable in the dry and wet seasons, by M. Dupint, it appears that if we call the useful power of traction in summer 1·00, in winter it will only be 0·75, on account of the difference in the mechanical structure of the

roadway itself, arising from the influence of the changes of the atmosphere. The mean average of the useful power of traction for the whole year is, according to the same experiments, 0·875 of that of the summer months; but evidently these results can only be considered to be correct for the climate and road observed, because the duration of the frosty and rainy seasons varies considerably even in the same parallels of latitude.

Engineers are not agreed as to the precise ratios of the draught to the load; by some it is considered to be as 1 to 30, by other as 1 to 25, upon a level road in a good state of repair. Upon paved roads the traction is easier than upon macadamized roads in the proportion of 3 to 2; in summer, and with a single-horse cart, it is more favourable than in winter, in the average proportion of 100 to 87. The number of horses harnessed to the same cart, and the mode of construction of the latter, are able also to modify the ratio. Thus it has been ascertained that if the useful action per horse be in winter represented by the figures of the first column of the annexed Table, under the conditions therein cited, in summer it will become as in the second column:

1 horse	in a 4-wheel cart,	in winter	826;	in summer	991
2 horses	,,	,,	956	,,	1009
3 ,,	,,	,,	851	,,	985
4 ,,	,,	,,	828	,,	963
5 ,,	,,	,,	661	,,	872

The horses being supposed to be harnessed in a straight line. Upon paved roads it would appear that the friction is affected by the suspension of the carriage, but that the draught does not vary with a change in the number of the wheels; the experiments however upon which these conclusions are founded were not sufficiently numerous, or executed with sufficient precautions, to warrant their being received implicitly. Upon macadamized roads, neither the suspension of the carriage nor the number of wheels are considered to exercise any important influence upon the traction. In the case of the paved roads, the traction is found to diminish as the width of the tire increases, in a ratio which may be represented graphically by a hyperbolic curve, whilst upon macadamized roads the width of the tires does not affect the draught.

Sganzin states that upon paved roads the draught is not more than $\frac{1}{30}$ of the pressure of the load, and that upon a good macadamized road it varies between $\frac{1}{20}$ to $\frac{1}{25}$. Navier found that the proportion became $\frac{1}{14}$, under some circumstances, when the vehicle was moving at a trot. It must, nevertheless, be observed that the superiority of the paved roads is less marked in proportion as the velocity increases; it is very important when the carriage moves with the ordinary speed of a carrier's waggon; it diminishes sensibly when the average velocity does not exceed 7 miles per hour, and is nearly annihilated at a velocity of about 10 miles per hour. Thus, upon paved roads the efforts of traction necessary to overcome the pressure of the total load of 1 ton being considered to be,

For a heavy carrier's waggon	38 lbs.
For a coach travelling at the rate of 7 miles	45 ,,
For a carriage travelling at the rate of 10 miles .	75½ to 82 ,,

Upon unpaved roads these efforts become,

For a heavy carrier's waggon	66½ ,,
For a coach travelling at the rate of 7 miles	66½ ,,
For a carriage travelling at the rate of 10 miles . . .	80 ,,

The road leading to the West India Docks was laid down with wheel-tracks of dressed granite, so as to present a bearing surface of nearly equal uniformity to that

of a railway. Mr. Walker states that the effort required to draw a ton weight upon such a road is not greater than 12 lbs., whilst upon a railway it is usually about 11 lbs. Other observers however make the effort of traction requisite to move the above load upon the granite tramway equal to about 25 lbs.; and under the ordinary conditions of repair of such roads it would, perhaps, be safer to adopt the latter quantity.

It is much to be regretted that the greater number of observations which have been made upon the draught of carriages are incomplete, inasmuch as they do not record the diameters of the wheels and the axles, or the width of the tires. These details have a very important influence upon the amount of the friction. But from the elements we already possess, it may be considered, with a tolerable degree of certainty, that the average tractions upon the different descriptions of roads are, per ton load,

Upon a railway	11 lbs.
Upon paved tramway	25 ,,
Upou common paved road	45 ,,
Upon macadamized road	66½ ,,
Upon canals it would only be	2¼ ,,

Poncelet, in his 'Mécanique Industriel,' gives the following Table of the ratio of the draught to the total load, upon the various roads mentioned; the weight of the carriage is to be included. This is generally found in practice to vary between $\frac{1}{3}$ and $\frac{1}{4}$ of the total load.

Description of Road, supposed to be horizontal.		Ratio of draught to total load.
Natural clayey land, dry		0·250
Land hard, rammed and dressed very evenly		0·040
Road of sand and gravel, fresh laid		0·125
Ditto of macadam, in ordinary repair		0·080
Natural chalky and flinty land		0·165
Roadway paved with large square blocks: the carriage suspended;	walking	0·030
	full trot	0·070
Ditto in well-squared and carefully laid stones;	walking	0·025
	full trot	0·060
Ditto oak planks, not planed		0·022
Tramway, of iron, or very even and very hard granite		0·010
Railway, in ordinary repair		0·007
Ditto, in perfect repair, and the axles constantly greased		0·005

From these figures it would appear that the hardness of the surface of the roadway does not produce a corresponding difference in the tractive power.

In all vehicles the friction is of two descriptions; firstly, that caused by the axle, and secondly, that caused by the tires. The friction of the axles is sensibly the same, whatever be the diameter of the wheel; it is therefore often desirable to increase the latter, in order to diminish the proportionate effects of the friction of the axle to the total resistance. The friction from this cause is estimated upon ordinary roads to give rise to about $\frac{1}{5}$ of the total resistance.

The friction upon the tires appears to modify the transverse section of the wheel, so as to cause it to assume an elliptical curve after a few weeks' work; and it would also thence be fair to infer that the width of the tire is not really of much importance, so far as the maintenance of the road is concerned. The diameter of the wheel has far greater influence both upon the traction and upon the destruction of the road,

because the destructive influence is proportionate to the length of the parts in contact, and to the dead weight; and evidently, the greater the radius of the wheel, the flatter will be the arc tending to depress the surface. The bearing of course will not be uniform over the whole of the surface of contact, either in the longitudinal or the transverse direction. It will be at the maximum at the point through which the resultant of the pressure passes, and diminish gradually on either side of the longitudinal axis. At the same time the pressure in the transverse direction will be unequal in a manner proportionate to the deviation from the normal section of the roadway.

The augmentation of the traction arising from the inclination of the roadway is a function of the inclination; and if the weight of the carriage, with its load, be represented by P, that of the animals drawing it by p, and the vertical height by h, this augmentation will be expressed by the formula

$$t=(P+p)\,h.$$

Calling the coefficient of traction m, the expression by which it would be represented, in the case of a level road, would be Pm; and where any inclination exists, the formula for the total traction becomes $t=Pm+(P+p)\,h$.

Upon a theoretically perfect road no inclination should exist which would require the wheels of a carriage to be locked in descending, because the loss of power in ascending such an inclination is not compensated for by the increased power gained by the descent. If it were possible, then, the rate of inclination should never exceed the ratios of the draught to the pressure. That is to say, as the maximum economical inclination of railways is 1 in 200, those of paved tramways should not exceed 1 in 100; of paved roads, 4 in 100; and of macadamized roads, 6 in 100. But there are so many circumstances which may modify the advisability of any decision upon this subject, that it is very rarely that the above conditions can be observed throughout a road of any length, especially when the country it traverses is irregular in its configuration. Moreover, inasmuch as the velocity at which the vehicle travels has a sensible influence upon the resistance it encounters from the deviations from a horizontal line, it becomes necessary to make this consideration enter into the balance of motives for fixing the maximum inclination. Thus, for horses moving at the rate of 8 miles an hour, an inclination of $\frac{1}{33}$ appears to be the maximum which can be admitted, if they be desired to maintain their speed. For horses dragging heavy loads and walking, the maximum may be safely carried to $\frac{1}{20}$. Practically, however, these limits are often neglected, and it is by no means rare to meet with hills whose inclinations are not less than $\frac{1}{14}$.

From a series of experiments recorded in the 'Annales des Ponts et Chaussées,' 1838, it would appear that the effort exerted by animals in mounting a long continued inclination of various angles, increases for a certain period, and then decreases. The inference drawn from this is, that the animals do not instinctively always employ the same effort. When the inclination has been short, the animals frequently increase their speed, as though the excitement of the accidental obstacle induced them to exert greater power. This observation would also confirm the opinion of their incapacity for equalizing the effort to be employed merely by instinct.

Other Modes of employing Horse-power.—When it is desired to raise weights without transferring them to any great horizontal distance, a horse may be made to produce a greater effect when he acts by his weight than when he acts by muscular exertion: or, in other words, if the horse be made to ascend without a load and to place himself upon a stage, attached by means of a rope, or a chain, passing over a pulley to another stage carrying the load it is desired to raise, he will exercise a useful effort, which Hachette states to be occasionally six times greater than he could exer-

cise in drawing a boat. This estimate is probably exaggerated, but there must be so marked an advantage in making horses act by their weight, that it is strange that they should not be so applied, in mining operations, to a greater extent than they are at the present day.

In mountainous countries without roads, such as many parts of Spain and of India, it is necessary to transport goods by means of pack-horses. In such countries it also almost invariably happens that the race of horses is small and of inferior power; at any rate the description of food to be met with is not such as is suited for the larger and more dainty horses used in other more civilized districts. Thus we find remarkable discrepancies in the powers of the pack-horse from those of the hunter; and whilst we frequently meet with hunters able to carry 14 stone, or 196 lbs., for a distance of 6 to 10 miles, at a speed of from 10 to 12 miles an hour, it is rarely that pack-horses are required to carry more than about 300 lbs., at a rate certainly not exceeding, if it attain, 3 miles per hour.

In fact, if the most advantageous mode of using a horse be to make him raise loads by his mere weight, the most disadvantageous mode certainly is, to make him carry the load on his back.

Generally.—The maximum useful effect produced by a horse is, generally speaking, considered to be obtained when,—1. The daily power exercised varies from $\frac{1}{3}$rd to $\frac{1}{5}$th of that which he is able to produce, without speed, during a short space of time;—2. When the speed at which the horse travels varies from $\frac{1}{12}$th to $\frac{1}{15}$th of the greatest speed during a short period and without any load;—3. When the duration of the period of working varies from $\frac{1}{2}$ to $\frac{1}{3}$rd of the longest period during which it could be continued without seriously affecting the health of the animal.

The observations made by Mr. Gordon, upon the effect of the horizontal inclination upon the draught of the horses, show that a considerable difference exists between the results obtained in practice, from those which are indicated by theory. Calling the traction R, the total weight drawn P, and the ratio of the traction to the load k; on a horizontal road we have

$$R = k\ P.$$

Theoretically, on an inclined road we should have

$$R = k\ P + (P \sin a,)$$

a being the angle which the road makes with the horizon: as this angle is usually very small, we may without inconvenience substitute the inclination for the sine of a, as high at least as an inclination of 0·05.

Mr. Gordon gives the following Table of his observations:—

Inclination per yard.	Theoretical value of P for similar values of R.	Real value of P for similar values of R.	Difference.
0·000	11·000	11·000	0·000
0·005	8·800	,,	,,
0·010	7·333	9·900	2·567
0·020	5·500	8·355	2·855
0·030	4·400	,,	
0·040	3·667	,,	
0·050	3·143	5·859	2·716

It is probable that the diminished value of k may arise from the fact that roads with high degrees of inclination are generally in a better state of repair than when

they are more nearly approaching a horizontal line. In the present state of our knowledge, therefore, it may be considered that the calculations of the equivalent distances of horizontal and of inclined roads are more ingenious than correct.

See Hachette's 'Traité des Machines;' Navier's edition of 'Belidor's Architecture Hydraulique;' Sganzin, 'Cours de Construction;' Claudel's 'Formules à l'Usage des Ingénieurs;' Telford, Wood, Gordon, Walker, etc., upon the draught upon different kinds of roadways; and various communications to the 'Annales des Ponts et Chaussées.' See also Mr. Leahy's 'Practical Treatise upon Roads;' Sir John McNeil's observations; and Sir H. Parnell on Roads, etc. etc.

QUALITES OF THE HORSE.*

From time immemorial the powers of this noble and generous animal have been made subservient by man to the purposes of war. The predatory Arab, the chivalrous Cossack, the adventurous Roman, and the patriotic Greek have each in successive ages, and in various manners, trained him for co-operation and assistance in their offensive and defensive movements in the battle-field.

In the present time, as in the past, his great powers are equally engaged and appreciated; and no army can possibly be effective, or complete, without his valuable and arduous services.

The horse, as employed in European armies, may be classed under the following heads, viz. 'the Artillery,' 'the Heavy Dragoon,' 'the Light Dragoon,' and the Pack-horse.

For 'Artillery Horse,' see p. 246.

The heavy dragoon horse is, or ought to be, a description of animal between the artillery and light dragoon horse; but recent regulations respecting recruiting are rapidly removing the distinction once so prominent between the heavy and light dragoon horses.

The average weight which a heavy dragoon horse has to carry is about 18 stone 11 lbs., and includes the dragoon and his appointments: to this are added, on Service, one day's ration for the horse, weighing 20 lbs., and one for the man, weighing 6 lbs., making a total of 20 stone 9 lbs.; an immense weight for a horse to support, and necessarily requiring a powerful animal to move under it in rapid evolutions.

Heavy dragoons are principally employed in the field, in charging cavalry and infantry, attacking guns, and covering retreats.

There is no description of horse used in the Service which requires a more cautious selection in purchasing than the heavy dragoon horse; for if coarse and underbred, he is too slow for field movements; and if well-bred, but not possessing bone and substance, is too weak to carry the weight, and too light to withstand the shock of a cavalry charge. Perhaps a better description of what the war-horse should be, cannot be given, than that described by Virgil; which corresponds precisely with our idea of the heavy dragoon horse.

"Illi ardua cervix,
Argutumque caput, brevis alvus, obesaque terga;
Luxuriatque toris animosum pectus: honesti
Spadices, glaucique; color deterrimus albis,
Et gilvo:
At duplex agitur per lumbos spina; cavatque
Tellurem, et solido graviter sonat ungula cornu."

* By Opie Smith, V. S., 2nd Dragoon Guards.

The light dragoon horse ought to be faster, more active, and higher bred, than the heavy; as his duties in the field are generally performed in quick movements, such as carrying despatches, pursuing an enemy, etc.

Although light dragoon regiments are allowed to enlist smaller men than the heavy, still the average weight to be carried by their horses is nearly equal to that of heavy dragoons; which circumstance tends materially to militate against their speed, and consequently the utility of their operations.

The heavy and light dragoon horses are purchased between the ages of three and five years. The price granted by Government for each horse is £26. 5*s*., excepting the Life Guards and Scots Greys.

The pack-horse is employed on Service only for carrying regimental baggage, hospital and regimental stores, etc. He is generally a short-legged compact little horse, very strong, and sure-footed. Mules are sometimes used for the same purposes.

Age.—The age of the horse is determined by the appearance of the teeth, which vary according to the number of years the animal has attained, and may be easily understood by a slight attention to the subject; the amount, quality, and size of the teeth, indicating the respective ages. (See Plate.)

All cavalry horses, or horses intended for the Service, date their age from the 1st of May; but it must be very evident that there might be a variation of several months between the different periods of their birth: hence arise the terms "an early or a late foal." To this circumstance in particular, and the deception occasionally practised by breeders,—of knocking out the colt's teeth,—the Officer employed to purchase remount horses should direct his attention; or he will be liable to imposition, and subject himself to the annoyance of having his purchases rejected, on account of age, at the Head-Quarters of his regiment.

Cavalry remount horses are usually taken between the ages of three and five years. One year making a material difference in their market value, breeders and sellers, aware of this circumstance, occasionally endeavour to make the colt appear a year older than he actually is: to effect this, they force out the colt's teeth, which are naturally replaced by the permanent ones in succession; giving a false indication of the age of the animal. By an experienced person the deception is easily detected, and a very little attention to the subject will enable any one to do the same.

We will suppose a colt to be nearly three years old, the age most likely to be practised upon; he ought at this time to have two permanent and four milk teeth in his lower jaw: the seller wishes to pass him as rising four-year old; to do this, he knocks out the two teeth next to his permanent ones, leaving two permanent teeth in front and two colt's teeth at the corners; thereby showing that the colt is putting up his four-year-old teeth, although at the time he has not completed his third year.

It certainly requires some experience to detect, at once, this attempt at imposition; but the buyer should carefully examine the upper jaw, to ascertain if the teeth in it correspond with the lower ones; for the deception is frequently confined to the lower jaw, as being the most commonly examined. If the teeth do not correspond, depend upon it fraud has been attempted; for the upper teeth are usually shed before the lower ones. There will also be a wound-like aperture of the gums, not to be mistaken, or an attempt of nature to fill up the vacuum caused, which the succeeding permanent teeth are not sufficiently developed to do. These indications, added to the small and young appearance of the front pair of nippers, and colt-like formation of the animal, will in most instances be a sufficient guarantee against deception.

The lower front teeth or nippers are those by which the age of the colt is usually determined. At two years old, these teeth will be complete; that is to say, the colt will have a full set, six in number, of milch teeth, as shown in the accompanying Plate.

Between two and three years old, the two centre teeth are displaced, and two permanent teeth succeed them, easily distinguished from the colt's teeth by being broader, larger, and having a dark cavity in the centre of the upper surface.

At three years old, the colt will have, in the lower jaw, two permanent and four colt's teeth: between the third and fourth year, the next pair of incisor teeth will be shed, and permanent teeth succeed them.

At four years old, there will be four permanent teeth in the centre, and two colt's teeth at each corner of the lower jaw. Between the fourth and fifth year, the last remaining colt's nipper or corner teeth will be cast; and if a horse or gelding, the tushes, four in number, will show themselves; two in the upper, and two in the lower jaw.

At five years old, the horse will have a full or complete set of permanent teeth in the upper and lower jaw; for the same change as stated to take place in the lower, is developed in the upper jaw also. The colt at this age takes the name of horse, and is supposed to be equal to all the laborious duties expected from him. Although we can no longer judge of his age by the shifting or shedding of his teeth, we can form a tolerably correct conclusion from other appearances of them.

At six years old, the dark oval-shaped mark in the centre of the two front nippers, usually called by horsemen "the bean," will be nearly or quite worn away; the tushes higher and stronger, and the cavities of the interior part of the tooth more filled; the two corner nippers level with the others, and equally developed.

At seven years old, the marks in the second pair of nippers are filled up, and the tushes become more round externally and internally.

At eight years old, the marks in the corner nippers are worn out, and the tushes more round and blunt. From this age, the animal is said to be, in horse phraseology, "past knowledge;" and although a tolerably correct opinion may be formed for many years to come, by the appearance of the upper jaw, and other prognostics, still they cannot be implicitly relied upon. It often occurs at a much earlier period, that the best judges of age are deceived by the untimely structural alteration of the teeth, produced by mechanical or pathological causes; such as crib-biting, biting the rack or manger, eating hard food, etc.; and the purchaser would do well, if he supposes that the marks are prematurely obliterated, to satisfy himself that the cause of erasure does not arise from the vicious habit of crib-biting.

The natural energies of the horse may be said to be at their zenith between the ages of six and nine years, and compared to the relative age of a man between twenty-five and thirty-five years,—provided that the functions of the animal have not been destroyed by early ill-usage, or over-work. Many instances of longevity in the horse are credibly attested; thirty, forty, and even sixty years have been attained. (See Plate 'Horse.')

As a particular instance, and one occurring of late date, we will mention, that at the review which took place on the 18th of June, 1846, in the Phœnix Park, Dublin, a horse, ranked, passed the General commanding, ridden by an old veteran, both horse and rider having been engaged in the ever-memorable battle of Waterloo: supposing the horse to have been five years old at the time of the engagement, he must have been, at that review, at least thirty-six years old; and the probability is that he was much older.

Mode of Supply.—In the year 1855, the war with Russia causing a greater demand

for Artillery and Cavalry horses, it was found necessary to alter the usual method of obtaining horses, that is, of purchasing young and untrained animals; consequently an order was issued to buy in future horses from five to nine years old, the prices for Artillery horses to be £42, and for Cavalry £40; the horses, to be hard fed, and in good working condition. For a time this system worked tolerably well, until the demand became greater than the supply; but it is not to be expected that the same class of horse is to be obtained as was formerly purchased under the late system. When an Officer was sent formerly to a fair to purchase young horses, that is, three years old, he had the first choice of those offered at that age in the market. Now feeders or dealers have that choice; when the horses are four years old, the Officer has a greater number of competitors in dealers, feeders, and persons requiring horses for their own use when the horses become five years old. The Officer has to select from those horses which are left after those persons alluded to, viz. dealers and feeders, have made their selection; in short, he has to choose from nothing but the culls, and of course of the most inferior description; it is therefore evident that Her Majesty's troops having the last choice, will have the worst horses. This should not be the case, and would be prevented if Government would purchase (as before the war) all available and promising young horses of three and four years old at the former price, viz. £26. 5*s*., let those horses be turned to grass in properly selected places, such as the Phœnix Park, Ireland, and in the winter let them have hay, turnips, or a little corn, a shed to go into in severe weather, but not fastened; in short, let them be treated as farmers treat young horses; when four and a half years old, let them join regiments or depôts; at five years old they would be broken and fit for any duties: while at grass a few pensioners, under the superintendence of an Officer, would be quite sufficient to take charge of them.

Every encouragement and every inducement should be given to farmers to breed horses, and if Government would provide stallions in different districts, whose services should be free, or at any rate at a nominal price, it would tend much to that purpose.

The Stable.—It is impossible to lay down any general rules to regulate the construction of private stables; existing circumstances, such as situation, elevation, size required, number of horses to be accommodated, means of the proprietor, etc., must be considered, and will govern the formation; but this is not the case with the building of Barrack Stables, there being generally plenty of ground, and a sufficient site to construct any description of stable building. The principal calculation to be made is, the number of troop horses to be stabled; and as stations are usually intended to contain whole regiments, squadrons, troops, or detachments, very little difficulty arises on this head. The next considerations are, the shape of the building, the number of horses each stable should accommodate, and a prudent attention to ventilation. Experience proves that the most sheltered stables are the most healthy; that is, those most sheltered from high winds and excessive currents of air; but so constructed as to allow of a pure and free ventilation of that element, provided that the situation is not low or swampy.

When stables are built for the reception of single troops, or detached parties, the site, shape, and arrangement will necessarily be much governed by the situation, locality, and other circumstances; but where ground is to be laid out for the purpose of stable building, for the accommodation of whole regiments, or even squadrons, then it becomes a matter of great consideration what is the best plan for convenience and utility, as well as to secure the health of the horses which are to occupy them. I have already stated that stables exposed to strong currents of wind are highly objectionable, and that those which are most sheltered are the most healthy. As it frequently happens that there is no natural or artificial shelter available for the pur-

pose, I consider that the best shape for the construction of troop stables is that of a square, or squares; so that from whatever quarter the wind may blow, one side will always present a screen or barrier to the tempest, and protect in a great measure the three remaining sides from its violence, and afford shelter to the horses during exercise or parade within its area. The size of the stables is a subject requiring much consideration, and to which sufficient attention is not generally applied: small stables are like small rooms, which are always very hot or very cold; and, generally speaking, all attempts at ventilation produce in them direct draughts, or injurious currents of air. Troop stables ought to be large enough to hold at least twenty horses. To effect this, I would advise that the stables be sufficiently wide to admit of the racks and mangers being attached to the walls on either side of the building, and a sufficient space allowed for a passage in the centre, wide enough to prevent the horses from reining back upon each other. In a long range, the stables should have doorways between each; so that in warm weather, when thrown open, a free circulation of air would be kept up from one end to the other, at the same time affording an easy method of communication. Too many entrances to the stables should be avoided; two are quite sufficient, one at each end, and answer every purpose for ingress and egress; at the same time they operate as most efficient and useful ventilators. In the small troop stables, as now generally constructed, the horses occupying the stalls on the reverse side to which the door is attached, are exposed, when the doors are opened, to a direct current of air; while those in the other corners suffer from impure atmosphere and want of ventilation. It is a curious fact, that during the prevalence of influenza, and other epizootics, I have noticed that four cases out of five occur with the horses standing in corner stalls; while those occupying the stalls exposed to the current of air from the open doors, have been afflicted with paralysis, and even locked-jaw.

I would recommend that the space of one stall, in every stable, properly partitioned off, be appropriated for the keeping of the daily rations of hay and corn, as great waste is often occasioned by its being placed in an empty stall, or exposed, outside the stable, to the inclemency of the weather; and that the space between the horses, in the centre of the stables, be sufficiently wide to allow the litter to be piled up on rainy or boisterous days.

The racks, mangers, and posts, to be made of iron; in fact, too little wood-work cannot be used in the construction.

Particular care should be paid to the drainage of the stalls, but no more inclination should be permitted than just sufficient to answer the purpose. Too great a declivity throws an injurious stress upon the tendons of the hind extremities, causing sprains, spavins, wind-galls, etc.: an inclination of four inches from the top of the stall to the gutter or drain at the bottom is quite sufficient to answer the purpose of drainage.

To prevent the accumulation of urine, fæces, and other offensive matter between the interstices of the paving of the stalls, the stones should be so laid as to form, as nearly as possible, a flat surface;* cement, impervious to wet, should be used between each stone. The flooring formed by the small pebble-stones now very generally used, is of the very worst description, as it admits the urine to soak between them, completely saturating the sub-surface, causing the generation of the most deleterious gases, and moreover is constantly out of repair.

A great variety of opinions exist respecting the propriety of making ceilings to the

* Mr. Stockley strongly urges the use of metal gutters in the centre of each stall, running into trapped drains, as greatly conducing to the health of the horses and saving the straw.—*Editors.*

roofs of troop stables; but provided the stables are sufficiently lofty, say eleven or twelve feet high, and the ventilators judiciously arranged, I think it is of very little consequence whether they have ceilings or not.

The doors and windows should be so arranged, that in the summer time they might be left open: half doors are preferable to whole ones; that is, the doors should open half from the top and half from the bottom; the lower half being kept shut, prevents a horse escaping from the stable in the event of his getting loose. This arrangement for infirmary loose boxes is almost indispensable, as the sick horse can have the advantage of the pure air, without being exposed to rain or wind.

Stable, Management of.—Under this head are included, feeding, watering, grooming, exercise, ventilation, and all matters which appertain to the general management of the animal; so as to keep him in the best possible health, and in that condition which enables him to perform the duties required from him with the least expenditure of his natural functions.

Feeding.—The quantity of food considered sufficient to support the energies of the troop horse is twelve pounds of hay and ten pounds of oats; and, generally speaking, if the quality is good, it is found sufficient for the purpose. These rations are divided into three feeds, given, one in the morning, one at mid-day, and one in the evening. Bran is sometimes substituted for corn, mixed with water to form a mash; it acts as a mild laxative, and tends to prevent fever and costiveness. In winter, bran is usually given to troop horses once a week; but in hot weather it will be found advisable to give it oftener: from its laxative qualities and easy digestion, it is one of the best, at the same time one of the safest, remedies as an alterative, that the veterinarian or owner can administer. For the infirmary stables, it is indispensable; and no horse can with safety be physicked, unless he has been fed at least twenty-four hours upon it: made into hot mashes, and given at night in a pail, so as to steam the head of the patient, it is an excellent remedy for catarrhs and coughs. The usual allowance given by contractors, in lieu of ten pounds of oats, is eleven pounds of bran; which, from its light weighing, forms a considerable bulk. Very few horses, although unfit to do much work when fed entirely upon it, lose their flesh or appearance. In all diseases of the digestive organs, hide-bound, fevers, etc., it is invaluable, and for which at present we have no substitute.

The properties of oats and hay are generally so well understood, that the subject requires little comment. All persons conversant with the management of horses know that musty and mow-burnt hay is highly injurious to their health, and should be carefully avoided: the same may be said of oats that are kiln-dried, or become sour by being placed in bulk when damp, or not properly harvested. Oats that are kept in store, in large quantities, should be turned over at least twice a week, or they will ferment, and become unwholesome: the neglect of this precaution has caused many Officers to reject corn as unfit to issue, which was perfectly good when passed into store.

Good meadow hay, which contains a full share of herbage, and well saved, is preferable to clover or any artificial grasses.

I have found great benefit from giving green food in summer, for a short time, not exceeding eight or ten days. Tares or vetches are preferable to clover; but when neither of these can be obtained, meadow grass is a good substitute: it acts gently upon the bowels and kidneys, prevents the necessity of medicine without materially altering the condition, removes swollen legs, cracked heels, hide-bound, etc. Horses should not work while eating green food; but as troops are at all times liable to be called upon to perform unforeseen duties, it is advisable that a certain portion only should be submitted at a time to this feeding, leaving the remainder fit for service.

Remount Horses—Stabling of.—The management, or what is generally termed the stabling, of young or remount horses, claims particular attention. No animal which man has domesticated, experiences so great and so sudden a change in his habits, customs, feeding, and exercise, as does the young horse when first taken up from pasturage, and placed in the stable; which is in future to be his almost constant dwelling. From freedom he is doomed to constant restraint; accustomed to seek his own food, he now eats nothing but what is served to him; from exercise dictated at will, he now obeys the direction of his rider; from pursuing the impulse of his own motives, he must now implicitly obey that of man; in fact, it is a change from nature to art,—from freedom to slavery. This change is indicated by the diseases which generally follow it,—strangles and fever are the most prevalent; and although not usually attended with danger, if proper precautions are adopted, still they have a decided influence upon the constitution of the animal.

When young horses are first placed in a stable, great care should be taken that it is kept cool and clean, with a proper supply of fresh air; and, above all, not to allow too many horses to occupy one stable. Their provender, at first, should be green food, if procurable, with oats; but if that cannot be obtained, bran mashes, or bran and oats mixed: but when given mixed, the bran should not be wetted; for if so, it enables them to swallow it without mastication. Young horses should be allowed as much water as they will drink; for this purpose a pail should be fastened within their reach, or, if the stable has iron mangers, a spare stall between each horse will allow of one manger being used as a reservoir. An occasional mild dose of physic will be found beneficial; excessive purging is to be avoided. As the animals become more accustomed to the stable, the bran may be reduced, and more oats substituted; at the same time the exercise should be increased.

Watering of.—Soft water, such as pool or rain water, is the best for horses: spasmodic colic sometimes arises from giving horses water just taken from a well or pump. Non-commissioned Officers should be instructed to pay particular attention to the watering of troop horses, as it frequently happens that an indolent or careless dragoon will not give his horse a sufficient quantity, if he has any distance to fetch it. I have known many horses fall off in condition by being kept short of water, and others to put up flesh, by having water so placed that they could help themselves at any time, or in any quantity.

Grooming of.—Many persons imagine that grooming is merely intended to clean the horse, and give him a fine coat; but besides these, its effects are much more beneficial, by producing circulation of the blood in the skin and extremities, and a certain degree of exercise.

It has become much the fashion of late years to expect in the troop horse almost as fine a coat in winter as summer: whether right or wrong we will not stop to inquire; but if it is demanded, I cannot conceive why the common means used in private stables to produce the effect, is denied to the troop horse. It is a well-known fact, that in every regiment there are many horses that have coats in winter of such a thickness and length, that the most laborious grooming will not make them look well; the slightest exercise causes them to sweat profusely, and it takes hours of grooming to dry them. Such horses are always low in condition; but what is of more consequence, they break down the spirits of the men who look after them; and moreover are an eye-sore to the regiment. In such cases I cannot help advising the judicious use of the singeing lamp, feeling assured that the horse would benefit by its application, both in condition and appearance; and the man would be saved a great deal of unnecessary labour.

Condition of.—There is no term in horse phraseology which bears so many and such widely different constructions as the word "condition."

The race-horse is said to be in condition when he can gallop at the top of his speed a given distance without distress or inconvenience to his natural functions,—a state of system brought about by the most artificial and even unnatural means.

The hunter is declared to be in tip-top condition when he carries his rider a long run, across a heavy country, without failure of wind or muscle.

The coach or post-horse, when he performs the stage allotted to him without sweating, or other symptoms of over-exertion; although every bone in his body might be counted through his skin. The dealer declares his horse to be out of condition while a bone of the ribs can be seen, and until every defect is hidden, as much as possible, by exuberance of flesh and fat.

The London dray-horse is considered out of condition until he represents, as much as possible, the last prize ox at Smithfield: and my lady's carriage horses, to be in condition, must be as sleek and fat as her ladyship's plethoric coachman and butler; and, like them, equally unfit for any exertion.

The term Condition, as appertaining to horses, can only be understood as relating to the purposes for which they are intended; and we shall therefore, in the present instance, treat of that state of the animal intended to be represented as the term is applied to the troop horse.

As the pace or severe exertions exacted from the race-horse or hunter are not demanded from the troop horse, we do not require for him the same artificial condition to which they are submitted; but as a certain degree of labour is imposed upon him in the performance of military duties, it is not proper or prudent to allow him to attain the same state of condition, as applied to dealers' horses. The desirable condition for the troop horse is, a naturally healthy state between the two extremes; not so fleshy as to incapacitate him for moderate exertion, or so poor as to prejudice the symmetrical proportions of his frame.

To bring about this desideratum, the co-operation of several agents is required, the principal being pure air, wholesome food, regular exercise, and proper grooming.

The want of condition is indicated by falling off of flesh, staring coat, frequently attended with hide-bound, or adhesion of the skin to the muscles, and sometimes yellow appearance of the membranes of the nostrils and eyes. When these symptoms are presented, the functions of the stomach and liver are deranged, and the digestive organs generally disordered: worms are frequently the cause of bad condition.

Many medicinal recipes are prescribed for conditioning horses; but the most certain is a proper attention to diet. Food easily digested should be given, such as bran, chaff, etc., and when procurable, green tares or clover; but when these are not to be obtained, oats or barley steeped in water, and allowed to germinate, are a good substitute.

Ventilation.—Impure air and imperfect ventilation produce more diseases among horses than all the other exciting causes of constitutional derangement; nor is it to be wondered at, when we consider that the animal, in his natural state, breathes the purest air of the plains and mountains; culls for his food the freshest and most wholesome herbs; seeks for his drink the most limpid and refreshing streams; exercises himself from the impulse of unerring nature; and recruits his strength by repose impelled only by the dictates of natural necessity. But view him in his domesticated state,—the slave of man, the living machine of his caprice and pleasure; chained a prisoner in a narrow space, twenty-two hours in every twenty-four; fed upon dried and fermented provender, according to the whim or means of his owner; worked in some instances beyond his powers of endurance; and in others his functions destroyed by the want of sufficient exercise; made to breathe air charged with the most loathsome impurities, and drink water often tainted and unwholesome; while his very rest is disturbed by the chains of his fellow-captives.

All air in stables is more or less impregnated with gases detrimental to the health of the animals; it therefore becomes the duty of those who have the charge of them, to lessen as much as possible the evil consequences arising from their existence. The most unobserving person must have noticed, on entering a close stable, a pungent, irritating sensation about the eyes and nostrils, frequently sufficiently strong to produce sneezing, weeping of the eyes, and head-ache: these sensations arise from the presence of ammoniacal gas (hartshorn), generated by the fæces and urine. If such effects can be produced upon man in so short a time, who is liable to breathe impure atmosphere, what must be the result of the constant inhaling of these gases upon the tender mucous membranes of an animal which in his natural state breathes the purest gales of heaven?—the answer is, disease, and even death. The category of diseases produced by impure air are principally inflammatory, and caused by its irritating qualities: of this class are inflamed lungs, influenza, catarrh, chronic cough, glanders, farcy, ophthalmia, blindness, etc. Mr. Youatt, in his valuable work, 'The Horse,' treating of this subject, states—"Mr. Clarke, of Edinburgh, was the first who advocated the use of well-ventilated stables. After him, Professor Coleman established them in the quarters of cavalry troops, and there cannot be a doubt that he saved the Government many thousand pounds every year. At first much evil was predicted; but after a time, disease that used to dismount whole troops, almost entirely disappeared from the army."

A horse consumes in twenty-four hours, in respiration, about 100,000 cubic inches of oxygen gas, the vital principle of atmospheric air; and when we consider that frequently eight, and sometimes ten horses, are made to stand in a stable not more than twenty-seven feet square, each horse consuming the same quantity of air, does it not appear imperative that every precaution should be taken to meet the demand?* The means to obtain pure air are,—allowing a sufficient quantity of it to enter the stable, and having apertures so placed as to permit the impure atmosphere to escape; keeping the stable clean; removing as soon as possible any evacuations; and avoiding any accumulation of manure, or bad litter, in the stable, or near the doors or windows. In badly paved stables, in which the urine lodges between the interstices of the bricks or stones, great advantage will be derived by occasionally sprinkling the floors with lime, which destroys the generating principle of ammoniacal gas.

Great care should be taken in making the openings for the purpose of ventilation, that all direct draught or currents of air upon the horses should be avoided. This can easily be done with the upper ventilators, by giving the apertures a slight inclination, from the outside of the stable, towards the ceiling or roof inside. With the lower openings, or those at the bottom, more difficulties are presented; but a slight glance at the great benefit derived by the admittance of air at the floor of the stable, will stimulate our inventive faculties to overcome them. Air impregnated with ammoniacal gas, which is always found to exist more or less in all occupied stables, from its specific gravity being much lighter than atmospheric air, has a natural tendency to ascend, and, where apertures are found, to escape; this will be much accelerated, if the partial vacuum caused is supplied by cold and dense air from the lower strata, the supply and escape causing a free ventilation from the bottom to the top of the stable. To avoid a direct current of air upon the horses, which this circulation would naturally cause, I propose that the air be admitted through openings made in the lower half of the doors, near to the bottom, faced by a piece of flat board attached to the sides by wedge-shaped pieces, the thinnest end at the bottom. This

* Mr. Stockley considers that not much less than 1000 feet of space should be provided for each horse in a stable.—*Editors.*

contrivance will cause the air to be thrown upwards, and prevent any draught upon the horses. The apertures can be closed or opened at discretion, by the application of a piece of wood to form a lid, to work upon hinges, thus, in figs. 1 and 2.

Fig. 1.

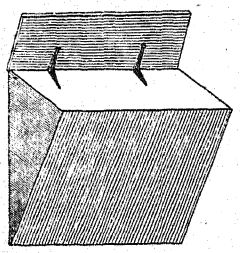
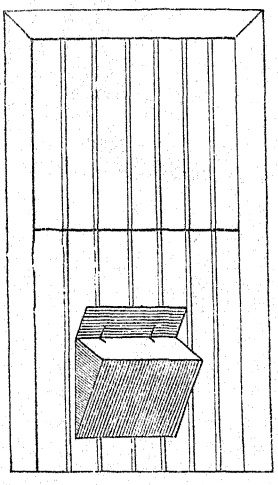


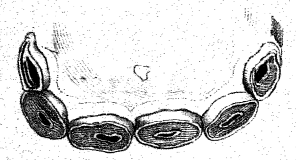
Fig. 2.



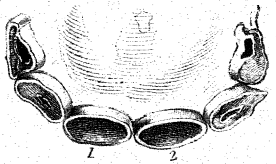
There is not much mischief to be apprehended from improper ventilation in the day-time, while the men are constantly opening the stable doors; but at night, when the doors are closed, is the time to observe precaution. The dragoon knows that a hot stable will save him a great deal of labour, by producing a fine coat without much of his assistance; and many a lazy fellow has stolen an opportunity to shut ventilators that have been left open by the non-commissioned Officer: such a man, when detected, deserves severe punishment. Generally speaking, the ventilators on the lee-side should never be closed; and in warm weather, all should remain open. Let it be remembered that cold pure air never killed a horse yet, but hot impure air has destroyed thousands.

BILLETING HORSES ON THE LINE OF MARCH.

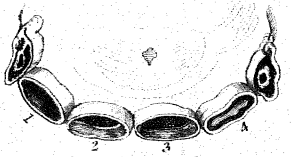
The indiscriminate billeting of troop horses on the line of march, or when called upon to assist the Civil Authorities, is productive of much disease, and will continue to be so until the authorities adopt some legal measures to prevent persons keeping glandered or farcied horses. Several well-authenticated instances are on record, where glandered horses have been removed from boxes or stalls to make room for Her Majesty's troop horses: in one instance upwards of twenty horses fell victims to the contracted disease, and in another fifteen horses were sacrificed; in both instances the propagated disease was traced to glandered horses kept by parties upon whom the troop horses were billeted. It is singular that no legal enactment exists which prevents persons keeping glandered horses. Not long ago one of Her Majesty's mails was horsed by glandered teams. Innumerable are the instances where men have died of the disease, and in one instance a whole family was sacrificed. Why not appoint an Inspector of Billets, assisted by the police, who are generally the billet masters? Let the billet master keep a correct list of all the billets within his district, and let the police receive instructions to frequently visit the billets, and en-



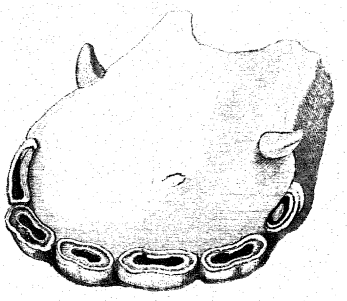
Two Years Old
All milch teeth.



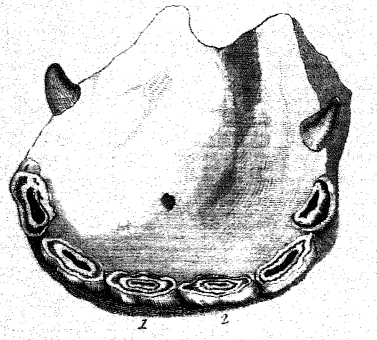
Three Years Old
Two permanent teeth.–



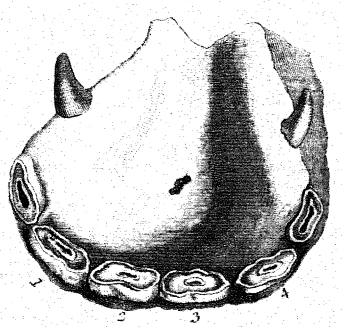
Four Years Old
Four permanent teeth.



Five Years Old
All permanent teeth.



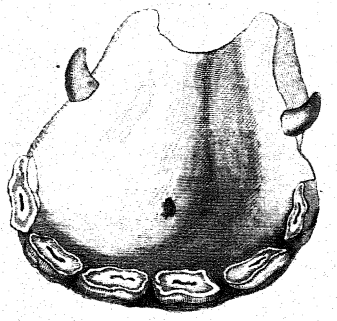
Six Years Old
Two cavities filled up.



Seven Years Old
Four cavities filled up.



Twelve Years Old.



Eight Years Old
All cavities filled up.

HORSE

Drawn by Smith, del.

London, John Weale, High Holborn, 1846.

W. Lowry, sc.

deavour to detect any diseased animal, or to ascertain if any glandered or farcied horse occupies or uses the stables. Where suspicion arises, the case should be immediately reported to the Inspector of Police, who should, without delay, communicate with the Inspector of Billets (who must be a veterinary surgeon); let him proceed to the place, examine the animal and premises, and report to the Quarter-Master General. If the animal proves to be glandered or farcied, a notice should be served upon the owner, desiring him to destroy the horse and purify his premises, under the inspection of the police, who will receive instructions for that purpose; should the owner refuse or neglect to adopt these suggestions, then let his name be posted at all police stations in the county, specifying the premises, and warning all persons from using his stables, and of course permitting none of Her Majesty's horses to be billeted upon him. Such a measure would be ruinous to any man's business, and would soon prevent glandered horses being kept by individuals, and much lessen the chances of infection. As the system of billeting is now carried on, it is almost impossible to march a dragoon regiment (particularly in Ireland) without contracting the disease of glanders or farcy. The only expense incurred by the adoption of the proposed system would be the salary of the Inspector, which would be doubly repaid by the number of horses annually saved.

O. S.

ARTILLERY HORSE.*

In selecting horses for the Artillery Service, the price, although sufficient for procuring such as are useful, will not admit of obtaining such as are remarkable for size and beauty; the former is not desirable, from the smallness of the ration on which they are to be fed, and the latter being much a matter of fancy: 3 years old, 15 hands; 4 years old, 15·2; and 5 years old, 16 hands, are heights fully ample to admit of sufficient power and action for the purposes required. The average weight of a 5-year old should be about 11 cwt. net, and 80 inches round the chest; and on this weight and measurement may be regulated that of other ages. It must be observed, however, that difference in growth and condition will occasion much variation. The above qualities will then depend on the form and breeding. Rotundity and length in the first will best give weight and power,—the depth from the withers to the brisket should equal that of the brisket to the coronet,—the ribs should arch from the spine, and descend circular to nearly the line of the brisket, inclining backwards so as to leave but a small space between the back rib and the stifle-joint,—thereby comprising being "well ribbed up." The loins should be broad, and somewhat convex,—the shoulder blade should be long and inclining,—the breast light at the points, but broad between the fore legs,—the fore arm long and muscular, with the elbow clear of the chest,—the shank flat and sinewy, filling well the grasp of the hand,—the fetlocks without inclining inwards, or weak, or long,—the feet circular, and somewhat concave on the soles,—the frogs full and elastic,—the quarters should be long from the hip-bones to the buttock points, full of muscle, descending far down the thigh,—the back wide and well defined, and the remainder of the limb having the same qualities as those described before, standing straight, and appearing firm on the ground. The head should be somewhat lean, and the countenance intelligent, with a neck gradually diminishing in size from the shoulders to the head: these latter parts and the quarters, with the tail set on high, more or less denote the breeding of the animal. The action should be quick, observing that the knee and hock are well advanced, and every limb as nearly as possible in a straight line. Colts however occasionally "dish," as it is termed, that is, swing their feet: when such is

* By W. Stockley, Esq., Principal Veterinary Surgeon, Royal Artillery.

outwards, it is of less importance, as it more or less ceases when the powers of their muscles become developed; but when inwards, it becomes an insurmountable objection to purchasing: as the age and soundness are within the province of the Veterinary Surgeon, his duties are necessarily defined by his profession, if he knows it.

VETERINARY DIRECTIONS.*

MASSES.—The ordinary dose of every mass is one ounce.

I.—CATHARTIC MASS.

One ounce of this mass made into a ball, is a dose of physic.—A ball contains seven drachms of aloes, the remaining drachm being made up with ol. olivar., ol. carui, and water.

Any horse to whom a dose of physic is given, should be fed on bran mashes, in lieu of corn, until its operation has ceased. If there be no cause for its immediate administration, let ample bran mashes be given, by way of preparation, in lieu both of hay and corn, during one day, and the ball administered the following morning, after the horse is sufficiently watered, and a couple of hours at least before his bran mash be given him. Exercise also, during the day, is advisable. The following day, early in the morning, after the horse has had water with the chill taken off offered him, till he refuses to drink more, let him be walked out briskly for one hour, unless he purge; in which case let him be returned to the stable, littered down, frequently watered, and plentifully supplied with bran mashes. But should the physic not operate at the expiration of his exercise, nor after he has remained four succeeding hours in the stable, let him be exercised for another hour; and he may be gently trotted at this time, should he still show no signs of purging: let it be here understood however that in no case is a horse in physic to be galloped. To ensure purgation, water is no less requisite than exercise.

Should the animal continue to purge on the third day, let his bran be eaten dry, and let him be kept short of water and without exercise, until the physic be set. As soon as his dung shall have put on its natural appearance and consistence, the usual ration of provender may be restored, and he may return to duty.

If the horse has been lately taken up from grass, or be low in condition, or light-carcased, six drachms of the mass is generally a sufficient dose; but if he be of large size, and in high condition, even nine drachms may be occasionally required.

Horses of a costive habit, whose dung-balls are small and not of their natural colour,—whose coats are rough and skins tight upon their ribs, and who do not thrive, require physic. Purging balls are also given with benefit to horses that have mange, or itchy skins—swelled legs, or grease—fever in the feet—inflamed eyes—staggers—locked-jaw—any swellings from blows or wounds, etc.

When a sick or lame horse requires physic, to whom exercise would be injurious, let the dose be increased by one or two drachms; and to him the ball may be given at any time—either day or night—he may stand in need of it, in order that its operation may be as speedy as possible.

To a horse not labouring under active disease, a second dose of physic is not to be administered prior to the seventh day; but to a *sick* one, should the case be urgent, the dose may be repeated at the expiration of twenty-four hours.

Horses suffering from coughs, discharges from the nose, or inflammation of the

* Suggested by Charles Percival, Veterinary Surgeon; and approved and promulgated for the guidance of the Farriers of the Royal Artillery.

lungs, are not to have full doses of purgative medicine given them, but the febrifuge or sedative mass should be given.

II.—FEBRIFUGE MASS.

A ball contains—aloes one drachm, antim. tart. one drachm, nitre two drachms, and common turpentine three drachms.

In fever, also in cough or discharge from the nose in which fever is present, this mass is especially useful; and if the fever be violent, the horse ought to lose three or four quarts of blood before the ball is given. Let the animal be warmly clothed—a hood be worn in catarrh—be littered down, have bran mashes, in lieu of corn, and be kept still and quiet in a well ventilated box. The ball may be administered once or twice a day, according to the symptoms; but it must be discontinued whenever it seems to affect the appetite, or should purging appear to be coming on. The appetite being restored and the dung in balls again, should it be required, the ball may be repeated.

III.—SEDATIVE MASS.

A ball contains—digitalis one scruple, antim. tart. one drachm, nitre two drachms, linseed meal three drachms, and treacle three drachms.

In cases of inflammation of the lungs, these balls are especially beneficial—a disease in which colds and coughs not unfrequently terminate. After having drawn four or five, or even six quarts of blood, according to the violence of the symptoms and the apparent strength of the animal, give a sedative ball three times a day at regular intervals. Let the sides of the chest be well rubbed with some of the blistering liquid, clothe warmly, and hand-rub the legs, making use of the turpentine liniment from time to time until they become warm, and bandage them with flannel. Keep the stable well ventilated.

Should the symptoms continue unabated, four or five quarts more blood must be taken away at the expiration of four or five hours from the first bleeding, and the operation may be repeated again in six, should the animal continue unrelieved.

Let the horse be littered down, and have bran mashes. No exercise.

IV.—DIURETIC MASS.

A ball contains—common turpentine half an ounce, nitre two drachms, and sulphur two drachms.

Diuretic or urine balls may be given in all cases in which they may be required, one every third night; seldom is it necessary to administer one every other night, and still more rarely every night.

Should the flow of urine be abundant—the horse frequently making efforts to stale, and groaning in so doing,—or if he cannot stale, but appear to experience pain about the loins and hips, and to be stiff in moving those parts, diuretic balls must on no account be given.

Diuretics are beneficial in recent swelled legs; linen bandages and walking exercise being had recourse to at the same time. They are also useful in watery farcy, dropsy, and puffy or watery swellings of all kinds.

V.—ALTERATIVE MASS.

A ball contains—aloes one drachm, calomel one scruple, sulphur half an ounce, and treacle three drachms.

To ill-conditioned horses that do not thrive, notwithstanding they eat and appear

otherwise in health—to horses that rub themselves or that have small lumps or bare places upon the skin (not mange)—balls made up of this mass are serviceable: one may be given every day for a week, or every other day for a fortnight, unless the horse should purge, when they are to be omitted, and had recourse to again in the course of a week or ten days.

Bruised corn, hay cut into chaff, and frequent and full supplies of water, contribute to restore such horses to condition. Walking exercise once or twice a day, according to the strength and thrift of the horse, is also recommended.

VI.—TONIC MASS.*

A ball contains—blue vitriol one drachm, verdigris half a drachm, linseed meal four drachms, and treacle two drachms.

The balls may be administered with advantage to horses affected with farcy or under suspicion of glanders, after the swelling and inflammation attendant upon those diseases have been abated by bleeding, purging, and diuretic medicines.

Not more than one ought to be given in the space of twenty-four hours; nor on any account should the dose be continued unless the horse's appetite is good. As soon as he refuses any part of his provender, or appears to be in any manner affected by the medicine, let the ball be omitted.

VII.—ANTI-SPASMODIC DRAUGHT.

This draught is prepared for horses that become griped, after the following manner: mix together two ounces of spirits of turpentine and one ounce of tincture of opium, and add a pint and a half of warm water.

In mild cases of gripes this single draught will generally suffice, but in violent attacks, four or five quarts of blood ought to be immediately taken away, and the draught, after an interval of a couple of hours, repeated; also two or three ounces of the turpentine liniment should be well rubbed upon the surface of the belly. If no dung is passed, let the horse be raked, and have clysters of salt and water (about four ounces of salt dissolved in four quarts of water) thrown up every hour until the bowels be relaxed. When the horse continues to lie down and rise in the stall, and to roll upon his back, relief will frequently be given by walking exercise for ten minutes.

Those cases in which the symptoms do not intermit, and in which the pulse and breathing are much quickened, are not gripes, but *inflammation* of the bowels. Take away five or six quarts of blood without loss of time, and give a draught composed of eight or ten drachms of aloes dissolved in a pint and a half of hot water,† with the addition of an ounce of tincture of opium; inject clysters frequently, rub a blister upon the belly, composed of equal parts of oil of turpentine and blistering liquid, wrap the legs in flannel bandages, making use of the turpentine liniment to the legs, if cold, and clothe warmly. Water, with the chill taken off, should be plentifully given; or, what is better, water-gruel.

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* Arsenic has specific effect as a tonic on horses. I therefore recommend ten grains to be added to the present Tonic Mass.—W. STOCKLEY.

† In administering draughts to horses, the greatest possible care and attention are required: should the horse cough or make an attempt to do so, his head must be instantly lowered, otherwise a portion of the drink will be apt to find its way into the trachea or wind-pipe, which will produce most distressing symptoms, and often be followed by death. In lowering the head, a can or vessel of any kind should be held under the mouth to catch the drink as it escapes.

If the symptoms do not speedily subside, draw three or four quarts of blood again, and repeat the blister to the belly, and clysters, and turpentine liniment to the legs, if not warm.

VIII.—VERMIFUGE POWDER.

Three drachms of this powder, containing one drachm of calomel and two drachms of tartarized antimony, form a dose.

To be given in a bran mash at night to a horse having worms, and to be followed up by the administration of a dose of physic the following morning—paying attention to the directions already laid down under the head 'Cathartic Mass.' The powder and physic may be repeated in the course of a week or ten days.

IX.—ANTI-PURGATION POWDER.

This powder is composed of prepared chalk half a pound, cinnamon four ounces, tormentil three ounces, gum arabic three ounces, and long pepper half an ounce, reduced to a fine powder and mixed together, with the addition of gum opium.

An ounce of the powder, which contains only a scruple of gum opium, may be administered in a quart of gruel in cases of continued purging or scouring, every four or five hours, or as circumstances may require, but its use is to be discontinued when the purging is checked.

X.—DISCUTIENT POWDER.

This powder is composed of zinc vitriol three drachms, and bole armen. one drachm.

A lotion composed of half an ounce of this powder and one quart of water is a proper application to sore backs, and to recent swellings from blows or injuries of any kind.

Bandages may be used, wetted with this lotion, in sprains of the back sinews.

XI.—ASTRINGENT POWDER.

This powder is composed of linseed meal half an ounce, powdered alum half an ounce, blue vitriol half a drachm, and bole armen. two drachms.

This powder is prepared principally for grease and thrushes; but it is also a good dressing for unhealthy sores—or sores in which there is proud flesh.

In cases of grease, when the discharge is but little, and not very offensive, besprinkle the affected parts with this powder: let the horse be exercised in the morning and afternoon; and if the legs be swollen, let a diuretic ball be occasionally administered.

But should the discharge be copious and fetid, apply to the heels, by means of pledgets of tow and linen bandages, a liniment composed of this powder and oil. This dressing ought to continue undisturbed for two or three days; during which time a dose of physic may be administered with considerable benefit. Let his food consist of bran mashes. As soon as the dressings shall have been removed, the animal ought to be exercised for two hours, the heels afterwards wiped dry, and the liniment again applied, unless the discharge have ceased; in which case the powder sprinkled upon the part, as above recommended, and a diuretic or two, will complete the cure. Should the case require a repetition of the liniment, purging balls are preferable to diuretics.

Of horses that have thrushes, lower the heels, that the frog may be upon a level with the heels of the shoe; pare out the cleft with a small drawing knife, so as to cut away the ragged parts of it, and introduce a little of the astringent powder daily,

at the evening stable hour. If heat be perceptible in the foot, a dose of physic may be given at the same time.

XII.—OPHTHALMIC POWDER.

This powder is composed of sugar of lead two drachms, turmeric half a drachm.

So long as the eyes appear red and angry, nothing but cold water should be made use of to them, with which they ought to be kept continually wet. At the same time, if there be much inflammation, take four or five quarts of blood from that side of the neck corresponding to the affected eye, or from both sides, should both eyes be bad.

When the inflammation is abated, sponge the eyes and eyelids with a lotion, made by dissolving a quarter of an ounce of this powder in a quart of cold spring water, several times in the course of the day.

In every case in which it is found advisable to draw blood, a dose of physic is recommended.

XIII.—BLISTERING LIQUID.

This liquid is composed of cantharides four ounces, and linseed oil a pint and a half.

For sore throat, and *jugged* swellings, in glanders or farcy—for inflammation of the lungs, and inflammation of the bowels, the blistering liquid is a proper application.

For spavins, splints, old strains, curbs, ring-bones, wind-galls, thorough-pins, and other enlargements of joints that have no heat in them, and swellings in general which will not yield to simple remedies, this liquid may likewise be used.

Let a small quantity of it be well rubbed in with the hand—without the hair being cut off—and let the same be repeated at the expiration of six hours, should it not have taken effect.

About one table-spoonful of this mixture is sufficient for the throat, two for the leg, three for the side of the chest, and so on.

XIV.—TURPENTINE LINIMENT.

This liniment is composed of equal parts of spirits of turpentine and linseed oil.

In cases of sore throat and cough this liniment will be found very useful, as well as in cases of inflammation of the lungs, and fever, where the legs are cold, making use at the same time of flannel bandages, and repeating the liniment every two or three hours, until they become warm.

Half an ounce will be found sufficient for a leg, or for the throat, and requires to be well rubbed in.

XV.—TURPENTINE OINTMENT.

It is composed of equal parts of common turpentine and hog's lard.

This ointment is the best application that can be made use of in case of treads or wounds on the coronet, between hair and hoof: a small quantity is to be spread upon a pledget of tow, and bound on with a bandage. It is likewise a good dressing for broken knees or cuts, and to promote the action of rowels.

XVI.—BLACK OIL.

It is composed of olive oil one pint, spirits of turpentine half a pint, and acid vitriol two drachms.

In recent wounds, such as broken knees or other lacerated wounds, this will be

found a good dressing to promote healthy and speedy granulation. It may be applied to extensive wounds by means of a feather, and in cases of broken knees a pledget of tow is to be bound on with a tail bandage.

It is likewise a good application for sitfasts, produced by the pressure of the saddle.

XVII.—HOOF OINTMENT.

This ointment is composed of tar and train oil, equal parts.

This ointment is intended for brittle feet, or such as have sand-cracks.

By mixing one part of the ointment with two of train oil, it forms a good application for mange.

HORSE POWER.*

As this is the universal term used to express the capability of first movers of magnitude, it is very essential that the estimate of this power as a dynamical unit should be uniform.

On the continent of Europe generally, the power of a steam or mechanical horse is estimated upon the original experiments of Watt and Boulton, which assigned to the horse a power of transporting 150 lbs. when travelling at the rate of 2½ miles per hour. This estimate was doubtless in excess, and as it was the interest of the buyer of machinery to increase it, and of the seller to diminish it, as the machine would be respectively equivalent to a less or a higher horse power, the necessity of reducing a vague estimate into a definite dynamic unit was apparent. Preserving, therefore, Watt's estimate, it was reduced to a dynamic unit as a vapour or mechanical horse power, and stated to be equal to 75 k. m. (*id. est*, kilogramme-mètres) per second; of 75 kilogrammes raised one mètre per second, or 4500 kilogrammes raised one mètre per minute, which is equivalent, in English weights and measures, to 543 lbs. raised one foot per second, or 32,580 lbs. raised one foot per minute. This estimate being generally adopted on the continent of Europe, it ought to be admitted by English Engineers; or, for practical purposes, the unit may be taken in round numbers as 33,000 lbs. avoirdupois raised one foot per minute, which is the practice of a majority of our manufacturers of steam engines.

A horse travels 400 yards, at a walk, in 4½ minutes; at a trot, in 2 minutes; at a gallop, in 1 minute.

He occupies in the ranks a front of 40 inches, and a depth of 10 feet; in a stall, from 3½ to 4½ feet front; and at picket, 3 feet by 9.

Average weight = 1000 lbs. each.

A horse, carrying a soldier and his equipments (say 225 lbs.), travels 25 miles in a day (8 hours).

A draught horse can draw 1600 lbs. 23 miles a day, carriage included.

In a horse mill, a horse moves at the rate of 3 feet in a second. The diameter of the track should not be less than 25 feet.

The expense of conveying goods at three miles per hour per horse team being 1, the expense at 4½ miles will be 1·33, and so on; the expense being doubled when the speed is 5⅓ miles per hour.

The strength of a horse is equivalent to that of 5 men.

The unit here adopted as a vapour or mechanical horse power is even somewhat greater than it would have been if strictly calculated on Watt's estimate of 150 lbs., so

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* By Colonel Portlock, R.E., F.R.S.

that it is desirable to ascertain what may be assumed as the dynamic unit in the case of draught, in the actual exhibition of horse power. Mr. Wood, after numerous experiments, reduces the power of traction of a horse to 125 lbs. when moving at the rate of $2\frac{1}{2}$ miles an hour, and supposing his efforts continued for 8 hours in the day; therefore $\frac{2\frac{1}{2} \text{ miles}}{60 \text{ minutes}} \times 125 = \frac{13{,}200 \text{ feet}}{60} \times 125 = 27{,}500$ lbs. Mr. Wood had previously estimated the powers of traction at 112 lbs., according to which the dynamic unit would be 24,640 lbs.; and others have carried it lower, or nearly equivalent to 22,500 lbs. But it is further desirable to understand the manner in which this principle of a dynamic unit of effective force is carried into practice, as a difficulty is occasionally felt in distinguishing between the actual value of the physical force exercised by a horse, and the compound resultant of its operation in draught. It has been stated by M. Regnier, that the extreme effort of a good horse is sufficient to overcome a resistance of 400 kilogrammes, or about 883 lbs.; but this effort could not be continued, and it is therefore necessary to adopt a standard suited to the regular and continued action of the animal—namely, 125 lbs., as given by Mr. Wood. If the weight to be moved be supported, the resistance to be overcome is that of friction, and will be in relation to the nature of the support, thus:—

Sledge moving on wooden rails.—Friction 0·70 of weight on first starting, so that the weight which one horse could move with ease would be 167 lbs.; but this might be estimated higher, as the friction is less after the sledge has commenced its motion.

A carriage on an iron rail or tram-road.—In this case Mr. Wood estimates the resistance at $8\frac{1}{3}$ lbs. per ton, or about the 264th part of the load: hence the practicable load, under such circumstances, of a horse is 33,000 lbs., moving as before at the rate of $2\frac{1}{2}$ miles an hour for 8 hours.

A carriage on an ordinary road.—The friction of a common cart, the axles being in proper order, has been estimated at 0·08 of the load: hence the practicable load will be $\frac{125}{0{\cdot}08} = 1562\frac{1}{2}$ lbs. Mr. Haswell estimates it at 1600 lbs. continued for 23 miles.

If all these numbers be reduced to the same form of dynamic units, they will stand thus:—

Vapour or mechanical horse power .	33,000 lbs.	av. moved 1 ft.	per minute.
True traction horse power, at 125 lbs.	27,500 lbs.	,,	,,
Do. do. at 112 lbs.	24,640 lbs.	,,	,,
Do. do. at 100 lbs.	22,000 lbs.	,,	,,
Draught horse power, sledge and rail, estimated on 125 lbs.	36,740 lbs.	,,	,,
Do. carriage and iron rail, estimated on 125 lbs.	7,260,000 lbs.	,,	,,
Do. cart on road, estimated on 125 lbs.	343,750 lbs.	,,	,,

The vapour horse is however considered to act continuously for 24 hours, and the traction horse, under any of its applications, only for 8 hours; so that the vapour horse is equivalent to 3·6 traction horses of 125 lbs.; 4 of 112 lbs.; or 4·5 of 100 lbs.; to 2·7 draught horses with sledge; to 0·013 of ditto with carriage on iron rail; or to 0·29 of ditto with cart on road.

Mr. Wood, on the assumption of 125 lbs. moved 20 miles per day at the rate of $2\frac{1}{2}$ miles per hour, and of the friction of carriages on iron railroads being $8\frac{1}{3}$ lbs. per ton, gives nearly 300 tons, conveyed one mile, as the daily performance of a horse. In the following Table, extracted from Mr. Haswell's 'Engineer's and Mechanic's Pocket Book,' a much lower rate of traction force is adopted, viz. 83·3 lbs.; and a

day's work of a horse on a railroad is estimated at only 115 tons, working $11\frac{1}{2}$ hours at $2\frac{1}{2}$ miles per hour, which, for 8 hours, would be only 80 tons; so that the friction is here estimated at 21 lbs. per ton. In using the Table for absolute results, these differences must be kept in view; but as regards the relative results at different rates of speed, they need not be noticed.

Table of the Amount of Labour a Horse of average Strength is capable of performing, at different Velocities, on Canals, Railroads, and Turnpike.

Force of traction estimated at 83·3 lbs.

Velocity, in miles per hour.	Duration of the day's work.	Useful effect for one day, in tons drawn one mile.		
		On a Canal.	On a Railroad.	On a Turnpike.
Miles.	Hours.	Tons.	Tons.	Tons.
$2\frac{1}{2}$	$11\frac{1}{2}$	520	115	14
3	8	243	92	12
$3\frac{1}{2}$	$5\frac{9}{10}$	153	82	10
4	$4\frac{1}{2}$	102	72	9
5	$2\frac{9}{10}$	52	57	7·2
6	2	30	48	6
7	$1\frac{1}{2}$	19	41	5·1
8	$1\frac{1}{8}$	12·8	36	4·5
9	$0\frac{9}{10}$	9·0	32	4·0
10	$0\frac{8}{4}$	6·6	28·8	3·6

The actual labour performed by horses is greater, but they are injured by it.

HURDLE.*—Hurdles consist of strong wicker-work of a rectangular form, and are occasionally useful in a siege, or in revetting field-works.

The best size for military purposes is 6 feet long and 2 feet 9 inches high. The same kind of picket will therefore answer as in making very strong gabions; and, generally speaking, the rods for hurdles should not be much less than an inch in diameter. An even number of pickets must always be used, and ten is a good proportion for a 6-feet hurdle, although woodmen generally employ only eight for a hurdle of that length.†

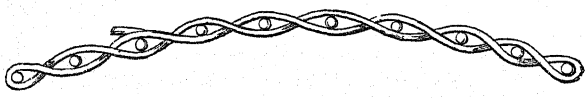
In preparing to make a hurdle, it is necessary to describe an arc of a circle on the ground, with a radius of about 8 feet, making the length of the arc 6 feet. This space must be divided into nine equal parts. A picket is then driven into the ground at each end of it, and others into every intermediate point of division, making ten in all. Then the wattling is begun on the same principle, nearly, as in gabion making, excepting that it is not worked round a circle, but in a continued line; and therefore when a rod reaches one of the extreme pickets at either end, part of it must be twisted like a withe, and be bent round the picket; after which it must be worked in the contrary direction.

The woodmen assert, that hurdles intended to be straight must always be curved in the first instance, as above directed, in order to prevent them from being crooked when pulled out of the ground, which they say that those made in a straight line invariably become. And in hurdle making, they use a wooden sleeper, moderately

* From the Course of Instruction at Chatham.

† The hurdles made by the Kentish woodmen are either 8 feet long, with ten pickets, or 6 feet long, with 8 pickets; and are usually 3 feet high.

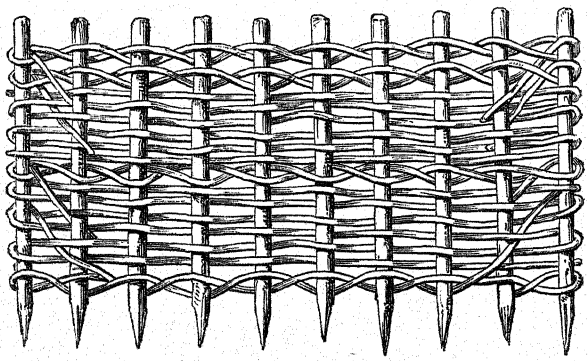
curved, with holes for the pickets on its upper surface, which they lay flush with the level of the ground; but it would not be worth while to make use of such sleepers in the field. The annexed figure is the plan of a hurdle commenced in a curve, according to the above rule.



In commencing a hurdle, the men work from the bottom upwards, as in gabion making, but the first rod is not pressed down close to the ground, excepting in the centre. Both its ends are raised about 9 inches above the ground, and there bent round the extreme pickets by twisting. Thus the first rods used form an arc of a circle, concave on the upper side. The second and third rods are bent round the extreme pickets, as close to the ground as possible, at each end of the hurdle, but in the centre they rise higher than the first rods used; and thus the first three or four rods, or rather courses of rods, composing the web of the hurdle, are interlaced in such a manner, by crossing each other towards the centre, as to prevent the separation of that part of the web from the pickets.

The ends of the rods are kept in their places by pressing against a picket, which jams them, and they are cut off about an inch in rear of it. It is not good workmanship to commence or finish with a rod by cutting it off in this manner close to either of the extreme pickets, as the twisted joint formed by bending the middle of a rod round those pickets evidently gives greater firmness to the work.

After having been commenced as described, the remainder of the web is worked up



in parallel horizontal courses, until it reaches the top of the pickets; and at this part one or two of the uppermost rods, after being twisted round the extreme pickets, are passed diagonally downwards in an oblique direction, towards the centre of the hurdle, passing through and between one or two of the pickets. This arrangement, which is also sometimes done about halfway up, as well as at the top, prevents the upper part of the web from separating from the pickets. The preceding figure represents a hurdle in elevation, just finished.

In making hurdles for civil purposes, it is usual to work by randing, or with single rods only; for the thick brush-wood generally used in this process is so stiff, that it requires an effort to separate it from the pickets. But as military hurdles would be exposed to greater strains than those used in husbandry, it is better to pair the rods in making them, which may either be done throughout the whole of the web, from

the bottom upwards, or at least for several courses at the bottom, middle, and top; for this undoubtedly gives greater firmness to the work. But the precautions before described for interlacing the lowest and finishing the uppermost courses of the web, render it unnecessary to use vertical withes for binding it, as in gabion making.

NUMBER OF MEN, TOOLS, TIME, AND WEIGHT.

The men and tools to be nearly the same as for gabion making, but with more bill-hooks than knives, and with a line ten feet long.

The probable time for making a 6-feet hurdle would be about three hours; and it weighs about 50 lbs. when the wood is dry.

HUT.*—Huts for military purposes are temporary buildings of wood or other materials, constructed in haste, to secure troops from the effects of weather in a better manner than tents will do, when it is intended to occupy ground during the wet season. Some remarks on the subject have already been made under the head of "CASTRAMETATION."

The experience of the Crimean campaign has strengthened the conviction that it is always best if possible to supply the troops with materials, and let them hut themselves; and the Committee appointed to investigate the matter reported favourably of only two classes of huts, one English and one Sardinian, the latter being constructed by the Sardinians with nothing but the brushwood, etc., found on the spot, except in the case of stables, for which they were supplied with scantling and boards for the roofs.

These huts are described as follows:—

"They are dug out about three feet; the roof, which is made of wattling or brushwood on rough rafters coming down to the ground, is covered with sundry coatings of mud, in which is mixed a small quantity of refuse chopped straw or hay. Each hut is calculated to hold six Infantry soldiers, or four Cavalry; the latter having their horse appointments with them in the hut. Each hut has its fire-place, and is quite warm and weather-proof: no signs of damp were observed in them. Where the ground was very rocky, instead of excavating, rough stone walls were built, and the roofs placed on them." (See figs. 1 to 6.)

The only English hut recommended by the Committee was the Gloucester, as conforming most nearly to the supply of simple materials. It is 28 feet long, 16 feet wide, about 6 feet high to the eave and 14 feet to the ridge. It will be best described by giving the contents of packages supplied, and the directions sent out for erecting them, as follows. (See also figs. 7 to 11.)

DIRECTIONS FOR ERECTING THE SOLDIERS' HUT.

Prepare and level the ground 28 ft. long by 16 ft. wide, the size of the building; and as much as possible provide small stones, gravel, or ballast 6 inches or a foot deep, for the sills to rest upon.

Unhoop the packages, and keep the pieces composing each together, with the letter mark exposed to view, for reference.

D contains the two end sills.

C, the four side sills; one 14 ft. 3 in. sill, and one 14 ft. sill for each side. Place these on the ground perfectly level; nail and secure the lap down, running a line or string along the outside, to keep the side sills straight, and measuring from corner to corner, to keep the frame perfectly square,

* Compiled by Captain Binney, R.E., from the report of the Committee appointed to report on the huts used in the Crimea.

I and *G* contain the posts. Fix them all in the sills, and drive them home, distinguishing the four angle posts and the four door posts with the notches inside for the transoms to run into.

C and *D* contain all the wall plates. Lay them on the posts, and drive home one of 14 ft. 3 in. and one of 14 ft. to each side.

D contains the end transoms.

H contains the side transoms. Drive them all home, flush with the outside.

N.B. It would now be desirable to keep together in place the angles of the hut by temporary braces, using a roof or side board.

F contains the rafters of the roof. Put them together on the floor, nailing on the collars and upright hanging piece in the centre; and lay the five roof frames upon each other, to preserve exactly the same span in each.

Get the exact span, measuring upon the floor from sill to sill, across the hut; then fix on and nail down the roof. In erecting the roof, brace each roof rafter to the sills by the roof boards.

N.B. The roof boards are made to project over the sides and windows about 4 in., but if it be wished, in situations not much exposed to wind, to give a greater projection or overlap, cut, upon the floor, the five rafters 3 or 4 inches shorter, as shown upon the plan *X* and *Y*, in the direction of the dotted lines, taking care to cut equal lengths off each rafter; the roof boards will then project further out at the eaves, and the roof itself be a little lower.

L, *M*, and *N* contain the side boards. Nail them on against the sills, transoms, and plates, keeping the tops well within the plates, so as not to prevent the roof boards being nailed against them. Put on the fillets over each joint of the side boards, nailing them well down.

The windows should now be fixed, and are intended to run outside upon the window fillets nailed against the boarding, and through into the transoms; and one fillet, also, for the top of the window, nailing against each window fillet a smaller one, to form a top and bottom groove for the window to run into; thus,  .

E contains purlins. Place them on the roof, and nail them to the rafters.

C and *E* contain the two ridge pieces. Lay them on the roof, and nail down.

J and *K* contain the roof boards. Nail them on, keeping the top ends clear against each other, and commencing from one of the ends of the hut, allowing a projection, or overlap, of about 4 inches at each end of the hut.

Put on the ridge cap, and then well nail down the roof fillets over each joint of the roof boards. One roof board in each of the compartments must have 4 or 6 inches sawn off, where the ventilator board must be placed, and nailed only at the top, so that it may be raised to give more air if required.

O contains the end boards. Commence from the door post, and leaving half an inch clear space inside of each door post for the door to shut against.

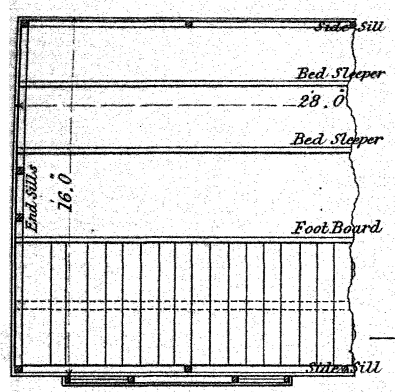
A and *B* contain the soldiers' bed sleepers. Fix them in the notches on the sills, nailing the 6 in. by 1½ in. sleeper against the posts on top of sill, the 7 in. by 2½ in. in the middle, and the 5 in. by 2½ in. in front; then nail the boarding; and afterwards place the foot board 2½ in. by 2 in. on the top of it.

NUMBER AND CONTENTS OF PACKAGES, MARKED W.E., IN EACH HUT.

A, 2 bed sleepers, 14 ft. 6 in. by 7 in. by 2½ in.; 2 ditto, 14 ft. 6 in. by 5 in. by 2½ in.; 4 ditto, 14 ft. by 6 in. by 1½ in.

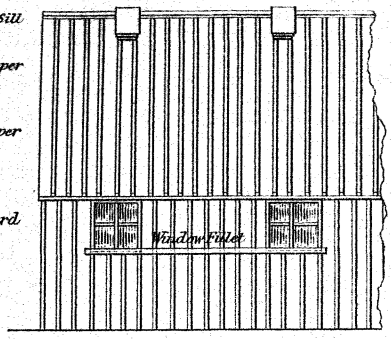
B, 2 ditto, 14 ft. by 7 in. by 2½ in.; 2 ditto, 14 ft. by 5 in. by 2½ in.; 4 foot-boards, 14 ft. by 2½ in. by 2 in.

THE GLOUCESTER SOLDIERS' HUT.



Half Plan.

Fig.7.



Half Elevation.

Fig.8.

PLAN AND SECTIONS OF A HUT AND STABLES, AS USED BY THE SARDINIAN ARMY.

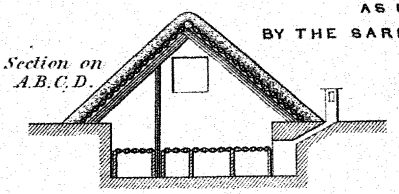


Fig.1.

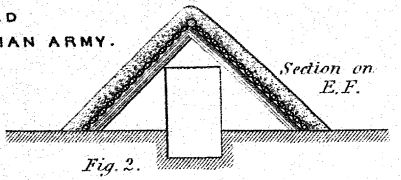
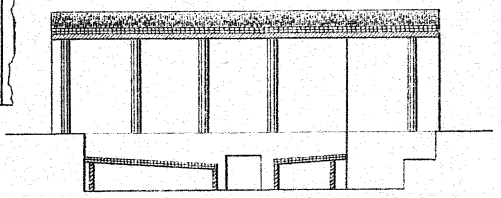
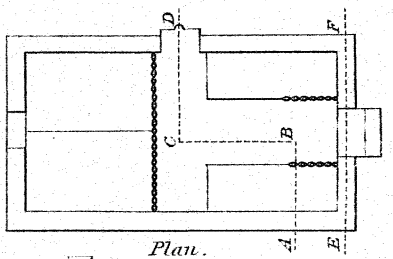


Fig.2.



Longitudinal Section.

Fig.3.



Plan.

Fig.4.

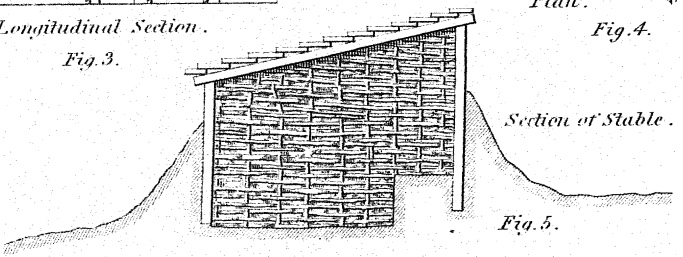
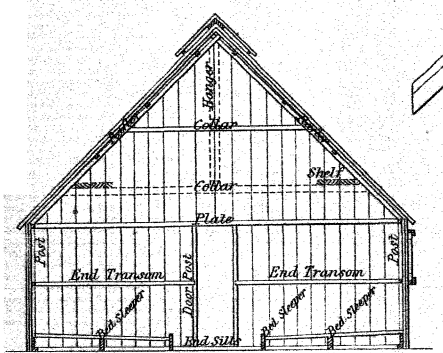


Fig.5.



Transverse Section.

Fig.9.

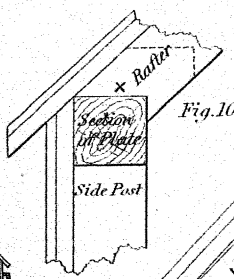


Fig.10.

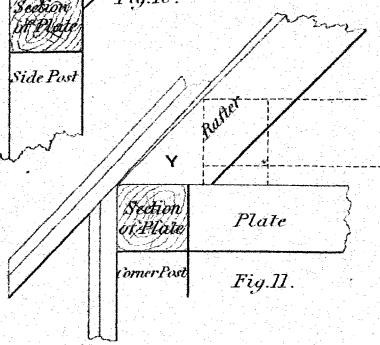
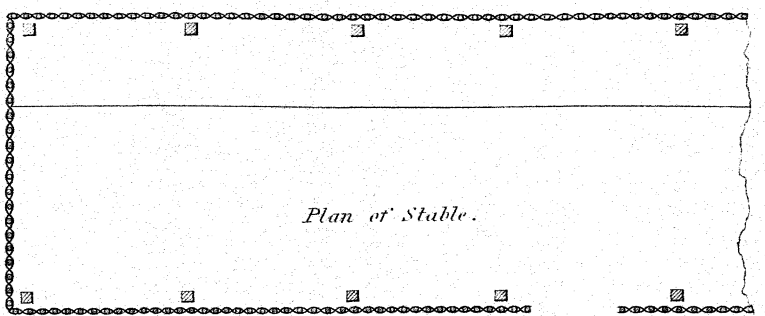


Fig.11.

Scale 8 Feet to 1 Inch.

8 7 6 5 4 3 2 1 0 8 16 24 Feet.



Plan of Stable.

Fig.6.

HUTS

London, John Weale, 1857.

W.A. Beever, Sc.

C, 2 sills, 14 ft. 3 in. by 3 in. by 3 in.; 2 plates, 14 ft. 3 in. long; 2 ditto, 14 ft. long; 2 sills, 14 ft. long; 1 ridge, 14 ft. long.

D, 8 window fillets or runners outside, 4 ft. 6 in. by 1½ in. by 1 in.; 2 sills, 16 ft. by 3 in. by 3 in.; 2 plates, 16 ft. long; 4 shelves, 16 ft. by 9 in. by 1 in.; 3 collars, 13 ft. by 4½ in. by 1½ in.; 4 end transoms, 6 ft. 6 in. by 3 in. by 2 in.

E, 8 purlins, 14 ft. by 3 in. by 3 in.; 1 ridge.

F, 10 rafters, 12 ft. by 3 in. by 3 in.; 3 ridge caps, 9 ft. 6 in. by 3 in. by 2 in.

G, 12 posts, 6 ft. by 3 in. by 3 in.

H, 8 side transoms, 7 ft. by 3 in. by 2 in; 8 fillets, 7 ft. by 1½ in. by ½ in.; 5 collars, 7 ft. by 3 in. by 2 in.; 3 hangers, 7 ft. by 3 in. by 1½ in.

I, 2 posts, 6 ft. by 3 in. by 3 in.; 2 doors, 5 ft. 7 in. by 27 in. by ¾ in.; 2 windows, 2 ft. 8 in. by 22 in. by 1½ in.

J (four of these), 14 roof boards, 12 ft. by 8 in. by ¾ in.; 14 strips, 12 ft. by 2 in. by ⅜ inch.

K (two of these), 15 roof boards, 12 ft. by 8 in. by ¾ in.; 15 strips, 12 ft. by 2 in. by ⅜ inch.

L (three of these), 14 side boards, 6 ft. by 8 in. by ¾ in.; 14 strips, 6 ft. by 2 in. by ⅜ inch.

M (two of these), 15 boards, 6 ft. by 8 in. by ¾ in.; 15 strips, 6 ft. by 2 in. by ⅜ in.

N, 12 boards, 3 ft. 3 in. by 8 in. by ¾ in.; 12 strips, 3 ft. 3 in. by 2 in. by ⅜ in.

O (two of these), 1 end package, 24 boards, and 24 strips.

P (five of these), 12 floor boards, 6 ft. by 11 in. by 1 in.

Q, 8 ventilators and fillets, 16 in. by 11 in. by 1 in.

One box, containing hinges, lock, bolt, 1 hammer, 1 gimlet, nails, screws, screw-driver, and lithograph of hut.

For *Hospitals*, the huts should, if possible, be double-boarded. The porch at one end to have the entrance door direct, for convenience of entry with a wounded man. The porch at the other end to be arranged for two privies, with large tubs placed under to receive the soil, etc., and a hinged door on the outside to be lifted, for the purpose of removing the tubs. The outer porch door would here be placed at the side.

The footings should be raised for a hospital hut, the ventilators at top large and carefully screened to keep out rain, etc., and the eaves should project not less than 18 inches, to carry all wet clear of the sides. Great care should be taken with reference to the stove pipes, each piece of which should have a shoulder, to prevent them slipping on each other.

In one of the Sardinian hospitals, a frame-work with shelves ran along the centre of the ward, for the cups, plates, etc., for the patients, the heads of whose beds were towards the frame-work; a plan approved by their medical officers, as obviating the risk from draughts and damp through the walls.

For *Stables*, the Committee recommended "scantling and boarding ¾ in. thick, to construct the roof; the boards being laid horizontally, and overlapping. Hooks or pegs should be fastened the whole length of the stable, for the horse appointments, and the walls constructed of mud and litter, which could slope outwards at an angle, the inside being supported by brushwood or staves of old casks. These walls are quickly constructed, and in warm weather, when they are not required, they are easily removed." These roofs would do without canvas. On level ground the horses may be in two rows, placed head to head.

The following paper contains most useful suggestions with reference to the construction of huts generally, as the result of actual experience.

"The best materials for constructing a hut should consist of scantling of two sizes;

the first 2 n. by 3½ in. thick, and 16 ft. long; the other 1½ in. by 3 in. thick, and 11 ft. long. The first should be for sleepers, wall plates, uprights, and joists; the other should be for rafters, ridge poles, and braces. For sleepers, wall plates, and joists, such scantling would answer in two lengths, for a hut 32 ft. long, and one length for the breadth. One length cut in halves would make two uprights, allowing the wall plates of the hut to be eight feet from the sleeper. The scantling for the rafters is the requisite length for a hut 16 ft. wide, so as to give the roof a good pitch.

"The sides should be boarded with ⅞-in. deal board, in 16-ft. lengths, and 11 in. wide. Thus, allowing 1½ in. lap, there would be sixty boards to a hut. The roof should be covered close with ½-in. deal board, also 16 ft. long, and 11 in. wide. Each roof would therefore require forty-eight boards, and six for the gables.

"The coarsest description of strong calico, two yards wide, and well tarred, would effectually exclude the rain. The doors and windows should be sent out ready made.

"The scantling and ⅞-in. board would do for making a camp bed the whole length of the hut.

"2-in. nails for the roof, and 2½-in. for the sides, with clout nails for the canvas, would be most efficient.

"The reasons for our coming to this determination are as follows:—

"The ordinary huts sent out in panels pack badly on board ship, by which a great deal of the stowage is lost. Boards and scantling would pack perfectly close, and no space would be lost.

"If any portion of a ready-made hut be lost or damaged, it is difficult to replace; whilst, with boards and scantling, huts can be made of the most convenient size, to suit circumstances.

"The present huts being all over ½-in. boards double, are much heavier than requisite. The ordinary felt is heavy, liable to damage, and very seldom renders the roof water-tight; whereas the calico would be light, readily applied, and much more effectual in excluding rain.

"From experience, we have found that the ordinary skilled labour in a regiment would, with little guidance, put up a hut of scantling and boards in less time than one of the prepared huts, and there can be no question of the boards and scantling being carried, either in carts or on men's shoulders, much more economically than the framed panels.

"(Signed) W. Bailey, Assistant Adjutant-General; F. Wakefield, Commissariat Works Corps."

HUTS OF A MORE PERMANENT CHARACTER.*

LOG HUT.†

Having been requested to explain the construction of *log huts*, I will accordingly endeavour to attempt a description of such as have fallen under my notice. In a country where timber abounds, as in the Canadas, the settler's first object is to make himself as comfortable as his circumstances will admit of, upon the lot of land destined for his future maintenance and happiness; to do which he usually commences by clearing part of his land of timber, separating the hard woods from the soft; the hard, such as maple, beech and birch, are usually burnt on the spot, and with the fir and spruce he builds himself a log hut.

* Compiled by Major-General Lewis, C.B., R.E.
† By Colonel Wulff, R.E.

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Fig. 1.—Plan of a Log Hut, showing notches A, to receive the next course of logs.

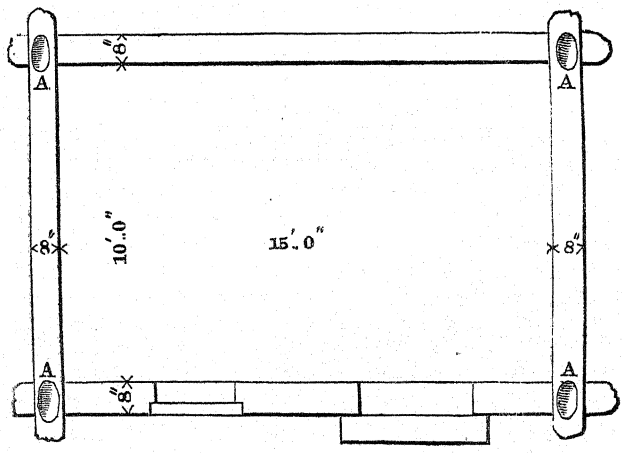
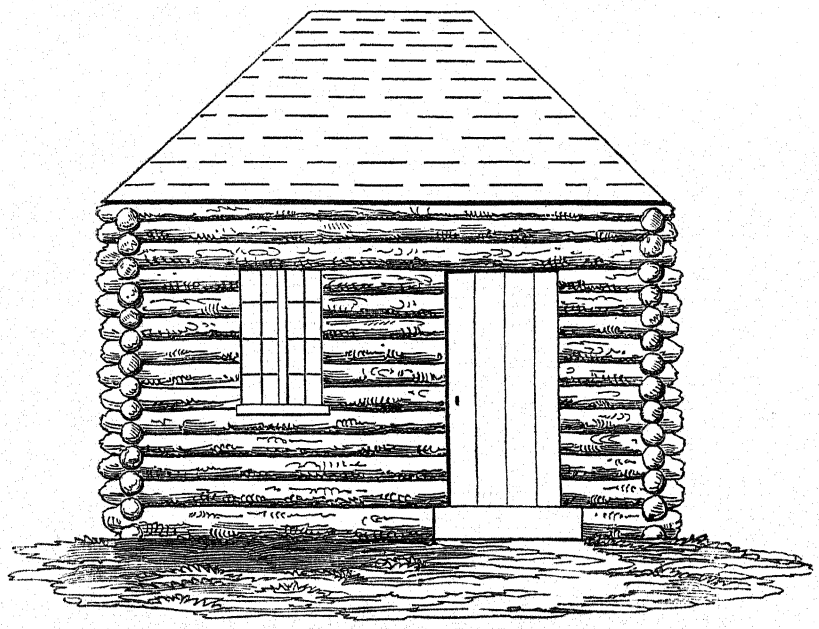


Fig. 2.—Front elevation.—(Scale 5 feet to 1 inch.)



The trees, after being felled, are cut into logs of sufficient lengths to match, and to suit the intended building. I will however suppose one according to the accompanying diagrams (figs. 1 and 2), which is the common size usually adopted in a primitive settlement. The bark is generally taken off, and the angle joints are formed by notching (see fig. 1, A, A) one log half its thickness into the other with an axe, and pinning them together: a projection of a few inches is left in each log at the

angles; the logs are thus carried up in courses to the intended height. The joints between the logs are then made water-tight by a stuffing of clay, or wattles, sallows, or small branches of soft wood; and these joints are then lined with laths, or the whole interior boarded, if inch boards can be had, which is preferable.

Fig. 3.—Plan of a Log Hut. Timbers squared and clap-boarded.

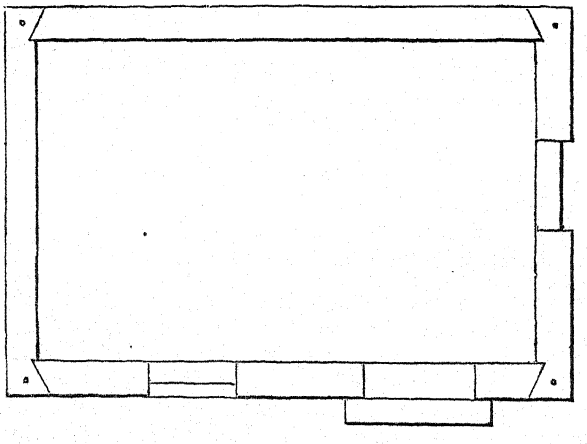
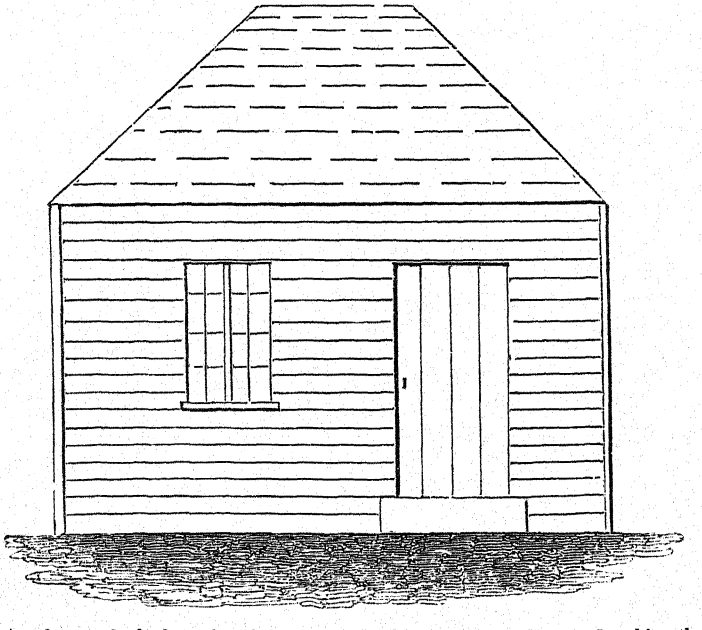


Fig. 4.—Front Elevation.—(Scale 5 feet to 1 inch.)



Another method of putting the logs together is, by squaring them, and making the angle joints either dove-tailed or halved (see fig. 3) into each other, and pinned with wooden pins: this gives a better appearance to the building, and the interior is less exposed to the weather, and it can then receive a better finish both within and with-

out. The outside is then often clap-boarded* (see figs. 3 and 4). It is usual to have a ledged door, and one or two windows, with glazed sashes and shutters. The roof may be framed with scantling of corresponding dimensions to Tredgold's Rules, or even of more slight materials; and covered either with boards to lap over each other, or boards laid flat and shingled, or with laths and shingles, or birch bark.

It is seldom that the poor settler can afford to build a chimney; his only means then left of warming his hut, which is indispensable in such a cold climate as Canada, is by a stove and pipe, the latter passing through the roof, having a clear space of about one foot around it, to receive a piece of sheet iron or block tin, which is let into the wood-work as a precaution against fire, in case the pipe should become red-hot. A wooden floor is desirable; but in many instances the settler resorts to a cheaper kind, made of the clay or soil on the spot,† mixed with wood ashes obtained from the cleared land, after the timber is burnt off: this mixture makes a tolerably durable terraced floor.

A hut of the former description may be built by two men in about a week; but of course without sashes, or any neat work which requires the more experienced hand of a good carpenter.—H. P. W.

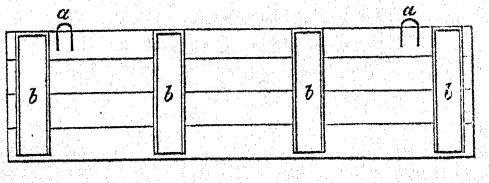
PISÉ HUTS.

Pisé Work.‡—Within a convenient distance of the spot, another must be fixed upon to supply the earth for the walls of the hut.

But it will be necessary to prove the quality of the earth before proceeding further; and for this purpose the vegetable mould, turf, or whatever the surface may be covered with, should be turned aside; and if the upper part appear sandy and poor, dig a little deeper, and if the quality does not at all improve, try another spot in the same manner; and having found some which has a richer appearance, or if such should fortunately be found on the first trial, it will come up with the spade or pickaxe in lumps: if it have stones amongst it, so much the better; and gravel which has a small portion of clay intermixed, which is known to labourers in England as good binding gravel, will be as good a sort as can be found. Anything, in short, will do but the poorest dry sandy soil or fat clay, and even these will make very good walls when mixed together, for doing which directions will be given as we proceed.

We must now direct our attention to the mould in which the walls are to be formed, which is very simple, but consists of several parts. We have not given any directions respecting this machine, but it ought to be provided before we arrive at this stage of the proceedings, because it will be better if made by a carpenter, and of seasoned materials; for on this depends not only the appearance but stability of the walls. If well made, there will also be much less trouble and difficulty in fixing it as the work proceeds. But it does not follow, that because a mould cannot be got which is made by a carpenter, and of the exact size and sort of materials here recommended, that earthen walls cannot be built; but, if made in any other way, the nearer the approach to it, the better will be the condition of the walls. And this remark will apply to every other part of these instructions, which are the best we can advise, where they can be acted up to, but which must be altered to suit the circumstances under which they are called

Fig. 5.



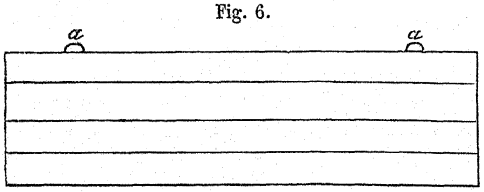
* Called weather-boards in England.—*Editors.* † *Vide* Article 'Castrametation.'—*Editors.*

‡ Common in the south of France.

into operation. The sides, which are the principal part of the mould, are represented in figs. 5 and 6.

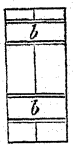
Fig. 5 is the back of one side of the mould, and fig. 6 is the front of the same side, In making each side, take well-seasoned deal boards, 10 feet long and ¼-inch thick, with as few knots as possible, and perfectly free from sap (which shows itself in blue streaks on the sides of such boards), and as many of them as will make, when finished, 2 feet 9 inches in width (fig. 5 shows four): they should be planed on both sides, and *grooved* and *tongued*, and *ledged*, which means strengthened by pieces nailed or screwed on the back, as shown by *b*, *b*, *b*, *b*, fig. 5. These ledges, of which there should be four, may be of the same sort of boards, 8 inches wide, and reach from the top to within half an inch from the bottom, where they are sawed off square.

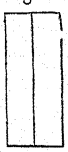
Fig. 6.



The head of the mould is made in the same way as the sides; only one will be required, and of the same width as the intended thickness of the wall, which we shall suppose to be 14 inches. Fig. 7 is the back of it, and fig. 8 the front. When in use, it is kept in its place between the sides by iron pins.

Fig. 7. Fig. 8.





The sides of the mould, when fixed, are supported by four bearers or joists lying upon the course or portion of wall, immediately under the one about to be raised; they are formed of square timber, 2 feet 6½ inches long, and in size 3 inches one way, and 3½ inches the other. The part which lies uppermost when fixed, which is 3 inches wide, is shown at fig. 9: *a* is the space on which the wall comes; *b*, *b*, are notches,

Fig. 9.

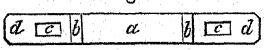
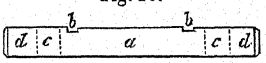
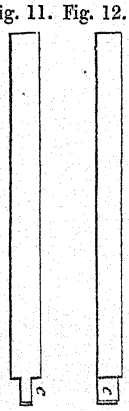


Fig. 10.



or grooves, into which the sides drop; *c*, *c*, are mortises, or holes cut through to the opposite part, 3 inches long and 1 inch wide; and *d*, *d*, are the ends left to protect the mortises. The same is seen at fig. 10, in the position in which it lies when the mould is fixed, the several parts being the same in both: the mortises are not to be seen in fig. 10, but their course through the wood is denoted by the dotted lines at *c*, *c*.

Fig. 11. Fig. 12.



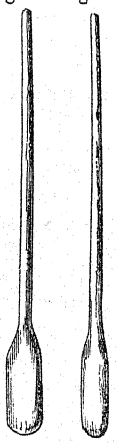
The length is thus made up:—

	ft.	in.
Space of the wall	1	2
Thickness of the two sides	0	2¼
	0	2¼
Length of the mortises	0	6
Two ends beyond	0	6
	2	6½

The upright stays or posts, of which there are eight, are pieces of squared timber of the same width and thickness as bearers, and 4 feet 6 inches long. Fig. 11 is the front, or that part which is next to the side of the mould when fixed, and fig. 12 is a side

view of the same: the parts at *c*, *c*, show the tenon, that is, a portion at the bottom of the post, 4 inches long, from which an inch in thickness is cut away on each side, leaving 1 inch in the middle, and half an inch off the back, which causes it to fit into the mortise of the bearers *c*, *c*, at figs. 9 and 10, in which they stand. Thus, 4 feet 6 inches being the length or height of each post; half an inch of the tenon will be seen under the bearer, 3½ inches of the same will be in the mortise, 2 feet 8½ inches will be the height of the side when dropped into the groove, and 1 foot 5½ inches of each post will stand above it.

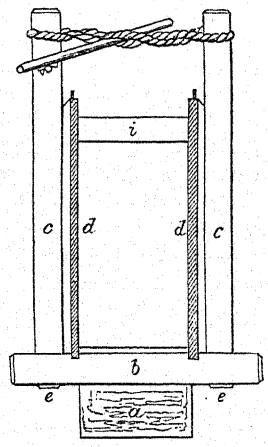
Fig. 13. Fig. 14.



The struts may be four pieces of wood of almost any description, with the ends sawn off fair; but if they are of the same size as the bearers, it will lessen labour, as will be afterwards pointed out. They are to fit in between and press the upper part of the sides of the mould against the uprights, and thereby give to the wall its proper thickness throughout.

We come now to speak of the rammer or beater with which the earth is rammed in the mould, which is a tool of greater consequence as regards the firmness and durability of the work than would be at first supposed. The form most likely to give the desired effect is shown at fig. 13, which is the front of the rammer; and fig. 14 is the same seen edgewise. It should be made of oak, walnut, beech, ash, or any other heavy hard wood; and if the butt end could be formed of the root of either of these sorts of wood, it would be the better, because that is always tougher and is less liable to splinter off. According to the form shown at figs. 13 and 14, it is 4 feet 6 inches long, 5 inches wide, and 2½ inches thick at the butt end, tapering up to the end of the handle, where it is 1¼ inch through it.

Fig. 15.



In order to show the position of the mould and of its different parts when fixed, we have, fig. 15, given a section of it, with a part of the underneath course of the wall, *a*; *b*, the bearer, lying upon it, which supports the sides of the mould, and in which the posts or uprights, *c*, *c*, are set and confined at the bottom by the mortises in the bearers at *e*, *e*. A small cord is wound three or four times round both posts near the top, and tied, and by passing a strong stick through the folds of the cord and twisting it, it tightens the sides, and if continued, would bring them too close to each other but for the strut, *i*, between the upper part of them, which prevents it: the end of the stick is then brought over a nail or peg in the side of the post, and confined there, which keeps the whole firm and tight together.

The four sides of the hut being now cut out on the outside of the line already marked, and at about 4 inches distant from it, cut a second line all round, which will be the outside of the foundation: dig a trench for the same, measuring from the outer line inwards about 1 foot 10 inches, and about 1 foot deep; but if in a very dry and firm soil, half this depth may do. In the same way mark out the partition wall, and dig a trench uniting with that of the front and back walls. Now, although bricks or stone are by far preferable for the foundation, it may so happen that neither are to be got; we therefore pass them for the present, and proceed to show how the

may be done without; and if, as before observed, the soil be dry, and some little precautions, which we shall hereafter recommend, be adopted, the earth which is taken out of the trench, with some of the roughest of that of which the walls are to be made, will do very well.

Having collected some large stones, the larger and rougher the better, throw them, intermixed with a small portion of earth, into the trench, as much as will cover three or four inches at a time; tread it down, and afterwards well ram it, not with the rammers made to work in the moulds, but with rough, heavier ones, such as the arm or part of the trunk of a tree. In the same manner fill in and ram for foundation of partition wall. Proceed in this manner till the trench is again filled up even with the ground, and ram well the ground along the edges of the trench, which will be a little broken.

We now return to the earth-heap; and, as was before observed, if the earth be too poor or too rich, it may be made of a proper quality by mixing: this is done by one man throwing up the poor earth in a heap, and another throwing into the same heap a shovelful of clayey earth to every two or three, or more, of the poor earth, according to the proportion which it will bear, and afterwards turning the whole heap over together, and chopping it about well with a shovel. Where it does not require any mixing, it is thrown up in a heap when dug, and the large stones roll to the bottom, and are drawn away with an iron-toothed rake. The teeth of the rake, however, should not be set too close, because stones that are not larger than a hen's egg may be used with advantage. If there are large stones and no small ones in the earth, they may be broken smaller and mixed with the earth. If the earth is dry, it will require a little wetting after it is dug and before it is put into the mould. This simple operation must be done very carefully, as too much wet would render the earth totally unfit for use: instead of suffering compression, it becomes mud in the mould; even if it be only a little too moist, it cannot be worked; it swells under the blows of the rammer, and a stroke in one place makes it rise in another, and clay, unless very dry, would do the same; therefore the water should be applied through a watering-pot, or by sprinkling it from a bunch of small boughs, so as not to make the earth in puddles.

In digging the earth, as well as laying it in the mould, take care to pick out every bit of root, great and small, all sprigs and herbs, pieces of hay, chips or shavings of wood, and, in short, everything that can rot or suffer a change in the earth, because, after a time, such substances will rot, and thereby affect the stability of the wall. Very little more should be dug at once than will be used in one day; and, if rain is expected, it should be covered up with boards or any other covering that may be at hand; and the unfinished walls should be protected in like manner.

The earth, having undergone this preparation, should be carried to the mould in a basket or otherwise, and strewed over the bottom to the thickness of three or four inches. One man should get into the mould, and spread it even with his feet, and afterwards tread all over it; but he must be careful, in getting in and out of the mould, not to disturb it by blundering against it. It must then be rammed, beginning at the sides, with a rammer such as that shown at figs. 13 and 14, until the blow leaves hardly any print or impression; and till then add no fresh earth. But as this rammer, from its form, cannot touch the corners, it will be as well to give it a blow now and then there, and close along the sides of the mould, with a piece of timber with the end sawn off perfectly square. For performing this part of the work, there should not be less than two men at the mould, and one to supply them with earth; they are placed on opposite sides of the mould, and should cross their strokes, particularly under the struts, and both should strike at the same time, so

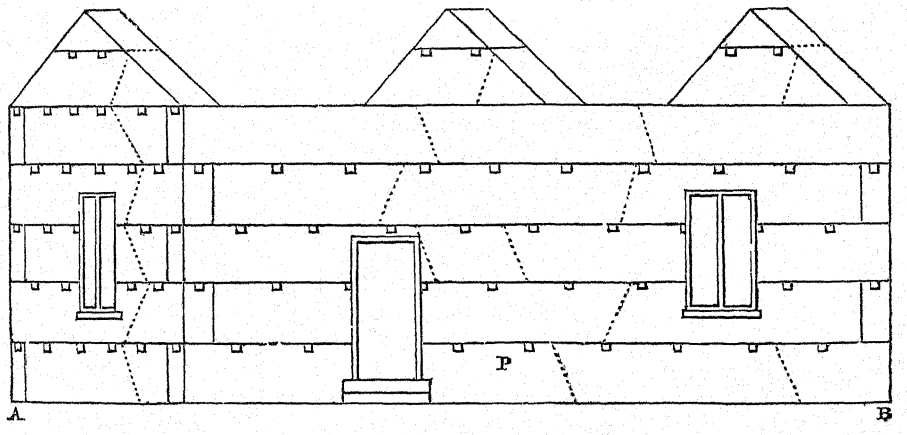
that the earth may be pressed equally in every direction, and care taken in beating against the head of the mould. If the struts were not in the mould, the sides would be slightly pressed towards each other at top by the earth being rammed in the lower part; but as the work proceeds, and the mould is rather more than half full, they will be pressed the contrary way, so that unless the struts are held by something more than the pressure of the sides, they will drop down and may be taken out; but one of them should be applied occasionally, to see that the sides do not spread too much, to prevent which, the cords must have another twist given to them, which will bring them to.

The head of the mould must be used in forming the angles or corners of the hut; and wherever a course of walling is to be worked against another, a portion of the middle of that which is already built should be cut out slanting upwards, and of the width of one-third of the thickness of the wall, by which means the walls will be more firmly united, and a straight joint through the whole thickness of the wall will be avoided.

To make good walls, it is not sufficient that the earths be well beaten, but they must be well united together: to effect this in houses of brick or stone, angles and binders of stone, iron braces, and cramp irons are used, which are very expensive. But here the binders cost very little; they consist only of thin pieces of wood, which are sufficient to give the greatest stability to buildings of this description.

The first course, P, fig. 16, being completed, begin the second; and as, for the course just finished, the mould has been directed from A to B, it must, for the second,

Fig. 16.



be directed in the contrary direction, which will cause the joints in the second course to lean to the right, those of the first course leaning to the left, as seen in the figure.

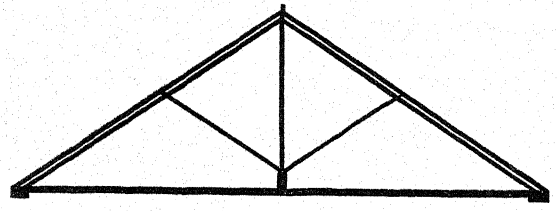
It should be observed, that if the struts are made of the same substance as the joists, a saving of labour may be effected; it is in this way,—by laying them in the mould in the situation which the joists will occupy in the course above, when it is full to within six inches of the top, and continuing to raise the earth on each side of them. When this is not done, the places for the bearers for the next course must be marked out, and small channels cut in the wall, to receive them; but as this will jar and unsettle the work in some measure, it is better avoided. Before this second

course is begun, a board about 5 or 6 feet long should be laid at the bottom of the mould, resting on the angle A, and extending lengthwise towards B, fig. 16. This board must be rough from the saw-pit, not more than 1 inch thick, and in breadth from 4 to 9 inches, according to the thickness of the wall, so that there may remain on each side of it not less than 4 inches of earth; by this means the board will be entirely concealed in the body of the wall, and when thus placed, neither the air nor damp can reach it, and of course there is no danger of its rotting. This board, from the pressure of the work raised above it, will contribute to bind together the two adjacent sides. Put in a similar binder to each of the angles, and also where the courses of the partition wall join to those of the exterior wall: the directions given for the second course must also be observed at each succeeding course up to the roof. By these means a great number of holders or binders will be formed, which sometimes draw to the right, sometimes to the left of the angles, and which powerfully unite the outer walls as well as the partitions; the several parts deriving mutual support from each other, and the whole being rendered compact and solid. Hence these huts, made of earth alone, are able to resist the violence of high winds, storms, and tempests.

RUBBLE MASONRY.

Rubble-masonry Huts, built of masonry in irregular courses, without faces or any dressing, when stone, should be selected of materials of moderate depth, and with even surface or bedding. Stone of 3, 4, and 5, and not exceeding 6 inches thickness, is frequently met on the surface in horizontal layers or beds, easily detached, and adapted to the thickness of the walls required for the hut. Rubble walls should be from 20 to 24 inches in thickness, laid in clay or lime mortar: the latter of course gives a greater durability to the structure. The principal care in this nature of building should be in laying the quoins or exterior angles, and to the doors or windows, and in carrying up the work horizontally upon a good solid foundation. For the description of stone necessary, and which is frequently found on the surface, see "STONE, BUILDING;" for it is not contemplated in the construction of huts, to quarry stone. In the event of such being the case, see article "QUARRYING."

Fig. 17.



30 feet.

Table of Scantling for Framed Roofs.

Span.	Tie-beams.	King-posts.	Principals.	Struts.
Feet.	Inches.	Inches.	Inches.	Inches.
16	8 × 3	3 × 3	4 × 3	3 × 3
20	9 × 4	4 × 4	4 × 4	4 × 4
25	10 × 5	5 × 5	5 × 5	5 × 5
30	11 × 6	6 × 6	6 × 6	6 × 6

Huts constructed of *pisé-work*, or *rubble masonry*, will bear a framed roof, and a heavy covering of tiles, slates, stone, or brick. The preceding diagram will explain the nature and size of the timber necessary in framed roofs for huts.

ROOFING.

Covering or Roofing of Huts is perhaps the chief difficulty, where mechanics are scarce and unskilful and the choice of materials limited. The usual resources for hut-roofs are, *Thatch*, *Shingles*, *Paper*, or *Felt*, where lightness is an object; and flat stones, bricks, and tiles, if the walls are sufficiently substantial, and care be taken in the construction of the roof.

Thatch, the easiest and generally most available, but objectionable on account of fire, may be obtained from low grounds, in the shape of reeds, rushes, and long grass; and in tropical climates, the plantain leaf and other vegetation of the like nature. Thatching is performed in the following manner when straw can be procured; but reeds and rushes, and long coarse grass, can be used by previously making them into bundles.

Thatching is a name given to a kind of covering over roofs: it is generally made of wheaten straw, laid on lathing and rafters, which may be of the same strength and placed the same distance apart as for a common slated roof; but in country places, where thatching is mostly used, the rafters are generally formed of the branches of trees of from 3 to 6 inches in diameter. The slighter they are the better, provided they are sufficiently strong, as the lighter the roof is, the less strain there is on the walls. Of course, if the rafters are stout, they should be placed further apart than if slight; and if the rafters are far apart, the lathing must be stronger, otherwise the thatching will bag, or lie in hollows between the rafters.

The straw is laid on the lathing in small bundles called "hellams," until it attains a thickness of from 12 to 16 inches; it is fastened to the rafters with young twigs and rope-yarn in a manner hereafter described.

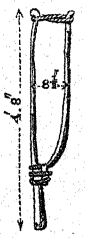
A good pitch for a thatched roof is 45°, or, as it is technically called, a "true pitch:" if the pitch is made less, the rain will not run off freely; and if a greater pitch than 45° is used, the straw is found to slip down from its fastenings.

A Description of the Uses of the Thatcher's Tools.

The thatcher's tools are—

A common stable fork.—This tool is used to toss the straw up together when it is wetted, preparatory to its being made into bundles for use.

Fig. 18.



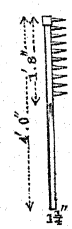
A thatcher's fork (fig. 18).—This is a branch of some tough kind of wood, cut with two smaller branches proceeding from it, so as to form a fork, as shown in the diagram: the joint of the two branches is generally strengthened by a small cord, to keep it from slipping when it is used. A small cord is fastened by one end into one of the ends of the fork, and a loop is spliced on the other end of the cord: this loop is made to pass over the other end of the fork, and to fit into a notch cut to receive it, as shown in the diagram.

This tool is used to carry the straw from the heap, where it has been wetted and prepared, up to the thatcher on the roof, where it is to be used.

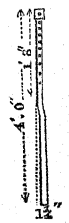
A thatcher's rake (figs. 19, 20, 21).—The handle should be of ash or some tough wood made not round, but square, so that it may be grasped firmly without

fear of its slipping round in the hand: the arrises may be slightly rounded off, to as not to hurt the hand. It will be seen by referring to fig. 20, that a crook is formed in the handle; the reason for this will be explained when we come to speak of the manner of using the different tools.

Fig. 19. Fig. 20. Fig. 21.



Thatcher's Rake.



Back of Rake.



Section of Rake.

The use of this tool is, after the straw is laid, to comb it down straight and smooth.

A thatcher's knife, or *eaves knife*.—This tool is similar in shape and make to the reap-hook, except that it is larger, and not curved so quickly.

The use of this tool is to cut and trim the straw to a straight line at the eaves of the roof.

The thatcher also requires a knife shaped something like a bill-hook, to point the twigs used for securing the straw.

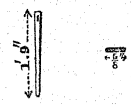
A half glove, or mitten, of stout leather, to protect the hand when driving in the smaller twigs, called spars.

A long flat needle (fig. 22).

A pair of leather gaiters, to come up above the knees, to protect his knees and shins when kneeling on the rafters.

A soft grit-stone, to sharpen the knives.

Fig. 22. Section.



Thatcher's Needle.

The Timbering and Lathing necessary for a Thatched Roof.

As before stated, the rafters for a thatched roof may be of round timber, such as the branches of trees, *and young trees*, of from 3 inches to 6 inches in diameter, placed not more than 14 inches from centre to centre; but sometimes the rafters are of sawn timber: in that case they should be cut about the same scantling as for a slated roof, not as for a tiled roof.

The lathing in a thatched roof being very liable to rot, it should be split out of heart of oak, or some other equally durable wood: the laths are about 1¼ inch wide, and ¼ inch to ⅜ inch thick, and are nailed on the rafters about 8 inches apart in a horizontal direction, just the same as for a tiled or slated roof.

If the laths are placed further apart than 8 inches, the straw is apt to bag or sink between them; the rain lodges in the hollows, and of course soon rots the straw.

An eaves-board about 7 inches wide is required to start the first part of each course of thatching upon.

A Description of the Manner of executing a Thatched Roof.

The rafters and eaves-board being fixed, and the lathing nailed on in rows at the prescribed distance apart before mentioned,—

As much straw is taken as it is thought will be required for the whole roof, which may be got at by estimating a square to take from 4¼ to 4¾ cwts. of wheaten

straw: care should be taken to keep the fibres or stalks as parallel to each other as possible. As each truss of straw is opened, it is spread out and wetted, using about 3 or 4 gallons of water to each truss: the straw is then tossed over and mixed together in one great heap with the stable fork, so that every part may get an equal portion of the water. If the weather is fine and dry, the straw may be used directly; but if the weather is damp or rainy, the straw should be allowed to lie for a day or so to drain, and be once more turned over.

The reason for wetting the straw is, to make it lie close, and to enable the thatcher's labourer more easily to draw the stalks out parallel.

The thatcher and his labourer being now ready to commence, the labourer spreads as much of the straw on the floor as will make a bundle 12 inches wide and 4 inches thick: the labourer then stooping down, with his left hand draws the straw, little by little, to his feet, and while doing so, he with his right hand draws out any loose straws that may be lying crosswise; by this means he gets a compact bundle of straw from 3 to 4 feet long, according to the goodness of the straw, and all the stalks are parallel. This bundle is called a "hellam." The labourer having placed 4 or 6 hellams crosswise in his thatching fork, carries it on his shoulder up to the thatcher on the roof, in the same manner as a bricklayer's labourer carries a hod of mortar: the fork is secured on the roof by a small peg and a piece of string.

The thatching is now laid in courses 3 feet wide, beginning at the right end of the roof, so that the thatcher works from right to left. The courses are laid parallel with the rafters, and not parallel with the lathing (as is the case in slating and tiling). Care must be taken, at starting at the eaves, to have a good firm body of thatch, letting the straw hang over, to be afterwards trimmed with the eaves' knife to a straight and good-looking edge. A row of three hellams is placed on each succeeding lath in the course, and each row of hellams is secured to the rafters with a young tough twig, called a ledger; it is about 4 feet long and an inch in diameter: each row of hellams is also secured to the row underneath it with three split twigs, called spars: the spars are about 2 feet long, and eight can be split out of a branch 2 inches in diameter; they are pointed at both ends, and are then doubled in two, and the thatcher gives them two twists round in his hand, in the same manner as a rope is twisted: this gives the spar a splintery surface, and enables it to hold on when driven into the straw.

The thatcher has a leather glove on his right hand; and keeping his hand flat or open, he gives the spar two or three smart blows, sufficient to drive it into the straw, and the leather serves as a protection to the hand. The spars must be soaked in water for some hours before they are used, in order that they should not break in the doubling up.

The *ledger* is a tough twig, about 4 feet long and 1 inch thick, as before described: one end is pointed, and driven or rather pushed 6 inches under the outside* rafter of the course; it is then brought over the top of two rafters, and over the top of the hellams, and then secured to the inside rafter of the course with about 8 feet of rope-yarn, by means of the long flat needle, thus holding down the row of hellams and preventing them from slipping off the roof.

The thatcher gives each course, as it is laid, a combing down with his rake, to get out the loose straws; he then takes a bucket of water, and throws it right

* In speaking of the outside and inside rafter of a course, it is meant, by the outside rafter, the rafter that is furthest from the thatcher; and by the inside rafter, the one that is nearest to him. And thus the inside rafter of one course becomes the outside rafter of the next course.

down the course, and gives the straw a good beating with the back of his rake, to break any stubborn straws and to make it all lie close; he then finally gives it another combing, and after that smooths it down with the back or flat side of his rake, and it is finished.

It will be seen by referring to figs. 19 and 20, that a crook is formed in the handle of the rake. The reason for thus crooking the handle is, to keep the thatcher's hand from contact with the straw, and thereby save his knuckles.

The ridge and hips are managed thus. The thatcher, in doing one side of his roof, takes care to leave a good length of straw hanging over and past the ridge. As he finishes the top of each course on the other side of the roof, he bends down the tops of the first side, and covers them over with the last row of hellams on the last side, bending these last in their turn down over the other side of the roof.

The ridge is then secured on each side with three rows of bands or spars, placed end to end, and each spar is secured with three other spars to the thatch.

In the case of the hips, there are no "bands" of spars; but single spars, 12 inches apart, are bent crosswise over the hip, and secured with three other spars, as before. The eaves are also secured with two rows, or "bands," of spars.

Where the side of a roof is high and much exposed to the wind, the whole ledgement is secured with these "bands" of spars.

To repair a thatched roof, the old thatch is left on; and another thickness of from 8 to 12 inches is laid on the top of it, the whole being done in just the same manner as described for a new roof, except that no ledgers are used. The greatest practical difficulty in thatching is, in joining one course to another so that there shall be no gutter between them; in fact, to do it in such a manner that the joints of the courses cannot be observed.

The way the thatcher manages is this: he lifts up the edge of his last course, and inserts the edge of the succeeding one under it; and then beats and smooths them down as even as possible. If care is not observed in doing this, six or twelve months will show bad workmanship; hollows like gutters will be seen at the joints of every course, and the water will penetrate into the underneath straw, and will rot it much before its time.

Wheaten straw thatching, done as here described, will last in our climate from fifteen to twenty years; oat straw, about eight years.

In the west of England (where the best thatching is done), they have a superior kind, called "reed-thatching." The ears of the wheat are cut off, *not thrashed out* in the truss; the truss is then wetted, and carefully spread out on a table, and one end is secured or held down by a board with a weight on it; the thatcher combs out all loose flags or broken straws, leaving only the clean sound pipe straw. To make a roof with this, the roof is first thatched in the common way, and then a thickness of 3 inches is laid on with spars only.

Other kinds of Roofing.

Shingles, or wooden slates, are made from hard wood, either of oak, larch, or cedar, or any material that will split easily. Their dimensions are usually 6 inches wide by 12 or 18 inches long, and about ½-inch thick. They are laid in horizontal courses of 4 or 5 inches, nailed upon boards, the joints broken, commencing with the eave course. The ridge is secured by what is called a ridge-board, or a triangle of inch stuff of 6 or 8 inches each side. In America, where this roof is common, the mechanics have a special tool for shingling, called a shingle-axe, with a hammer at the back.

Paper, Felt, and Canvas are sometimes available; they are nailed with scupper-nails, and then tarred over.

SITE.

Drainage and Site.—Every hut should be well drained, and the water carried away from the foundations, but the ground in the vicinity should be levelled and adjusted, to prevent water collecting. Hence every care should be taken that there are means for draining, and that the site should be sufficiently elevated to permit the water to be drained off freely. Except in the Tropics, the entrance of every hut, where possible, should face the mid-day sun, and the back of the hut be turned from the prevailing winds. The floor should be at least 8 inches above the level of the ground; and where building-stone and masons are to be had, then huts should have a foundation of 18 or 20 inches high.

In the selection of a site for hutting a Detachment or a Regiment, water and fuel should be as near as possible, more especially water.

For Troop and Artillery horses it is usual to leave one side of the hut, facing the mid-day sun, entirely open, and racks and mangers are not provided; and the back wall must be sufficiently strong to bear the pull and jerking of the horses' heads. In very bleak places, the front or open part may be closed in at night with bushes or tops of trees, to break off the wind.

ON THE MANUFACTURE AND CHOICE OF BRICKS.*

Every one is so familiar with the general qualities of brick, that it is almost needless to say it is a sort of artificial stone composed either of pure clay or a mixture of coal ashes and, in some cases, an addition of chalk to loam or clayey earth, which, after undergoing preparation, is tempered with water, formed in a mould, and dried in the sun; and afterwards, in most cases, baked or burned in a kiln, or in a clamp. The antiquity of bricks is also well known, the invention of them being carried by some even beyond the Deluge; but we have indubitable proof of the use of them, as well as the principle on which they are made at the present time, being known at as early a period as the building of the city of Babel by the descendants of Noah, for we are told that on their commencing that great work, "they said one to another, Go to, let us make brick, and burn them thoroughly; and they had brick for stone, and slime had they for mortar." Thus has the art of making bricks been carried through a period of four thousand years, almost without variation. The latter process in the art, that of burning, has been at times dispensed with, as it is at this day in some parts, in which case a quantity of straw is intermixed with the clay, to give the brick additional tenacity. Bricks made in this manner, however, will not bear exposure to the weather or fire.

There is and ever has been considerable variation in the size of the brick. The Romans—who were so bountifully supplied with marble and stone, that bricks were but little used in building till towards the decline of the republic—made them chiefly of large dimensions, and the relics of them preserved by the antiquary prove them to have been much the same in quality as our best kiln-burned ware. We have no information of the precise date at which the art of burning bricks in a clamp was introduced: the discovery and introduction of the use of coal, which is necessary to their composition, is comparatively recent, but that of applying it in the manufacture of bricks is much more recent, and indeed may be said to be modern; for clamp-burned bricks, or *grey-stocks*, as they are called, did not make their appearance till the latter end of the last century, and were not brought into general use

* Brick-making having been omitted in the first volume, it is introduced here, as some knowledge of the art is of great use for troops taking up quarters in the field, though of course they would not attempt to carry out all the arrangements.—*Editors.*

till the beginning of the present. They have, however, attained such a state of perfection, as far as building is concerned, that they have driven their flaming rivals out of the field wherever a choice existed.

The earth selected for brick-making should be clay of the purest kind, but where that is not to be found, an inferior quality may be made use of, provided it be free from stones.

In England, bricks are chiefly made either of stiff clay or of a yellowish-coloured fat earth, commonly called *loam*. The former produces the red bricks, which are burned in a kiln; the latter—which is the sort found near London and in the adjoining counties—when burned in a clamp, makes a neat yellow or grey-coloured brick. The quality of each sort as to hardness and fineness of grain, as well as colour, is varied considerably by the natural qualities of the earth, or by an artificial process which it is made to undergo.

Bricks are applied to various other purposes as well as for building, and these are manufactured where the clay is found which best adapts them for their several uses. We need only notice two of these, and that but slightly, viz. paving-bricks, and fire-bricks. The former, as is well known, are used for paving the floors of cottages and out-houses; they are made of various sizes, and are very hard and brittle, being made of clay in its pure state. Fire-bricks are used for building or lining the inside of furnaces, or such buildings as are exposed to a continual live heat, which some of this ware will resist more effectually than iron.

Building-bricks, as before observed, are of two sorts,—kiln-burned, which are of a red colour, and clamp-burned, which are grey, and are called grey-stocks. It will be as well for the reader to impress these terms on his memory, as we shall, in alluding to them in future, call the former *kiln-bricks*, and the latter *grey-stocks*.

The earth, of whatever quality, for making bricks should be dug in the autumn, and laid in a heap till the spring, so that it may have the benefit of the winter's frost,* which, by mellowing it, greatly improves its quality, and otherwise assists the labours of the brickmaker. As the process in making kiln-bricks is most simple, we shall for the present confine ourselves to them, and afterwards point out the difference between them and the grey-stocks. And here we would observe, that the light earths generally contain such a quantity of sand as to render the management of them very difficult: on the other hand, some of the stronger clays are improved and rendered more serviceable by the addition of a portion of sand,† which lessens shrinking and prevents cracking in burning.

Previous to beginning to dig the earth, the turf, or upper surface of the ground, should be pared off as great a space as may be required, and as much of the ground under it removed as is unfit for the purposes of brick-making, and laid aside; another space, a little below this, should also be cleared and made even, on which the brick-earth is to be laid as it is dug, and formed into a regular square heap of about 2 feet deep, which the workmen gauge by sticking notched sticks in the ground, and in this state it is left through the winter. Early in the spring, if the earth is of a nature to require the addition of sand, it is spread equally over the top of the heap, and in such proportion as the case requires.

As soon as the danger to be apprehended from frosts is gone by, which, in England, is generally about the latter end of March, brick-making is commenced. The brick-maker or *moulder* sets up his gear, consisting of a temporary shed near the heap, of a very rude construction, being merely four posts set in the ground, and a hurdle or two with straw run between the splints, for a shelter, laid upon the top,

* In cold climates.—*Editors.*

† Also to harden and even vitrify the bricks.—*Editors.*

and having a rough table under it, at which the bricks are moulded. Between the heap and this shed, the clay-mill, or *pug-mill*, as it is called, is fixed, which is made in the manner of a cask with staves and hoops, and rather wider at bottom than top —about 5 feet high, and 3 feet wide at the bottom; an iron spindle runs down the middle, working in a socket at bottom, and passing through an eye at top, where it has a beam attached as a shaft for a horse, by which it is turned. From the sides of this spindle strike five or six iron arms in different directions, and in these are fixed iron blades, also in different directions, which, by repeated divisions, thoroughly intermix the earth, which is put in at top, by the time it reaches the bottom, where it is forced out at a hole in the side,—a much less tedious method of preparing the earth than the old practice of kneading or treading it, though some will have it not so good an one.

A common barrow is used to convey the earth from the heap to the *pug-mill;* and two *off-bearing barrows*, which, instead of the box or body of the common barrow, have a light frame with a flat lattice top, about 3 feet high over the wheel, and 18 inches near the handles, so as to be about level when in work, are required to carry the bricks, which are laid in rows on them to be conveyed to the *hacks*.

The *hack-ground* is laid out between the moulding shed and the kiln or place intended for the clamp, and if there be a slight fall of the ground towards the latter, the better; slight elevations in straight rows are then formed, about 2 feet wide, and at a distance of about 5 feet from each other, for the *hacks*, which are the piles of bricks set up in their green state to dry, the surface of the raised parts being made perfectly even: a little fine earth or sand is sifted over them, as well as over the track between for the off-bearing barrow, which should run smoothly, or it will injure the newly formed bricks. The brick *mould*, which should be made by a skilful person, and with precision, is composed of iron or steel, but as it requires to be very light, the sides are strengthened by thin pieces of well-seasoned wood, over the edges of which the iron sides are turned and finished square; it must be somewhat larger than the intended size of the brick, to allow for the shrinking in drying and burning. The moulding-table being furnished with brick boards, a raised block with iron edges is laid on it, to receive the mould, and a quantity of fine sand; and all things being in readiness, the labourer whose business it is to supply the clay-mill, chops down a quantity of brick earth with a shovel or hoe, nnd turns it well over, to intermix the several parts, adding a little water in the operation, if necessary; then filling his barrow, he wheels it up a strong plank laid for that purpose towards the pug-mill, and shoots the contents in at the top, which he continues to do throughout the day. The horse being put in motion, works it down the mill and through the hole at the bottom, where it is cut off by a boy, with an iron instrument having a handle like a shovel, and carried to the moulder's table. It is here received by another boy or girl sitting on the right of the moulder, who draws off with the hands a piece rather more than sufficient to fill the mould, and works it into the shape of the mould, and it is then rolled towards the moulder, who takes it up in both hands, and dashes it into the mould, thereby filling up every part of it. He then takes in his right hand, from a bowl of water fixed in front of his table, a *strike*, which is a thin smooth piece of wood, and drawing it along the edges of the mould, strikes off the overplus, or as much as lies above the edges, which he throws back to the assistant on his right, to be again moulded. He then turns the mould over, and turns out the brick upon one of the brick boards, which he sets on a double iron rail at his left, along which they are slid by a boy, who afterwards places them on the *off-bearing barrow:* at the left-hand front corner of the table is the dry sand into which the moulder every time dips the mould, and dashes the inside well, to prevent the brick

from sticking. The bricks being laid each upon a brick board, are set upon the barrow, and after having some dry sand sifted over them, are taken away by the *off-bearer*, who is next in importance to the moulder; for if the bricks are moulded ever so well, an unskilful person, by handling them while green, would soon spoil the shape. Having arrived at that part of the ground where they are to be set, he commences the *hack*, in doing which he takes a loose *brick board* and places it on the upper side of one of the bricks, removes it between the two boards to its place on the ground, setting it on its edge and drawing the boards gently away: he then lays one of the boards on the barrow, and with the other proceeds as before till he has deposited the whole, when he returns with the barrow and boards, and another load is ready for him. In this way the hacks are set up two bricks in width, not straight across, but diagonally, or in a slanting position, and tolerably close. After the bottom row is completed, another *hack* is begun, because when the brick is just moulded it will not bear the weight of another laid on the top of it. When the bricks have *set*, or become sufficiently hard to bear the weight, they are piled one upon the other, generally to the height of eight bricks. After the bricks have stood in close order a few days, they are reversed and set more open, which allows the wind to pass freely, the bottom bricks being put at the top, and the top ones at the bottom. A sufficient quantity of long straw, rye being the best, and wheat next, for the purpose, is provided and laid alongside the hacks, and at night is laid gently on the top, and is then left till the weather is fine enough to allow of its being removed: some who make bricks on a small scale, have small sheds erected, covered with boards or thatch, under which the hacks are set; but the advantage of the sun's rays falling upon the bricks is sacrificed in such cases. the time allowed for drying the bricks will vary very considerably with the weather and other circumstances; but when they appear to be dry, they should be proved, by breaking through the middle one of them in different parts of the field, and they must not be put into the kiln until they are as dry at the centre as on the outside, or the heat, when applied, will cause them to fly to pieces.

The kiln is of various forms, and brick-built, having only one aperture in the sides. If made in the oblong form, which is the most simple, and to burn 20,000 bricks at a time, it should be about 14 feet long and 10 wide, and the walls not less than three bricks thick, and a little inclined towards each other as they go up. Flat arches are turned near the bottom, with spaces left at regular intervals, resembling lattice-work, through which the fire ascends. The bricks are set upon these arches sufficiently open at the bottom to allow the fire to pass, and closer at the top, where they are covered with old brick or tile rubbish, to keep the heat in; this being done, some wood is put in and kindled, to dry them thoroughly: when this is done, which is ascertained by the smoke having become more transparent, the mouth of the kiln is stopped up with old bricks, plastered over with clay or brick-earth, only just room enough for a fagot being left, and the burning is commenced by putting in fagots of brushwood, furze, heath, etc. The fire being thus made up, is continued till the arches assume a whitish appearance, and the flames appear through the top of the kiln, upon which the fire is slackened, and the kiln cools by degrees. This process is continued, alternately heating and slackening, till the bricks are properly burned, which is generally in the space of forty-eight hours. Very great precaution is necessary in thoroughly drying the walls of a new kiln with a gentle heat before the full power of the fire is used, or they will be sure to burst, whatever may be their thickness. This gradual drying is also necessary, for the same reason, in other works, such as ovens, or wherever a powerful heat is employed.

The process of making grey-stocks differs very materially from that of kiln-bricks.

The earth is dug at the same time and in a similar manner, but the earths employed in making them generally contain a quantity of sand, therefore there will be no occasion to add more; but earths containing too much should not be used, or the bricks will be very unsound, or what the workmen call *shaky* or *shuffy*, lying in flakes like a thick pie-crust, and, when struck against each other, will make a dull rattling noise. This is the case with most kiln-bricks, as well as inferior grey-stocks, but the best grey-stocks are as firm as a rock, and will, when struck, give out a clear ringing sound. In place, however, of the sand, a layer of coal or cinder ashes is laid over the brick earth, which is afterwards intermixed, first by the labourer, and then by the pug-mill. It is also prepared and moulded in the manner before described, with the exception of the sand employed by the moulder; this, for kiln-bricks, is such as is used to sift over the floors in public houses and kitchens of country houses, and may be either red or white, provided it be of sufficient fineness, and such is generally to be found in the vicinity of a brick-kiln. Not so for the grey-stocks; the only sand of which we have heard of being used with them, is procured from the side of the Thames at low water, near Woolwich; hence called Thames sand, which has a fine silvery grain, is free from grit, and of a greenish-white colour. With these exceptions, the process is the same up to the period of burning bricks, but for the clamp they require to be more uniformly dry than for the kiln, because in the clamp the whole force of the fire is applied at once, and continued. The ground upon which the clamp is to be set is raised and made perfectly level, and covered with old bricks set on their edges; on these are set the new bricks, with a flue or space of about 9 inches wide and 3 feet high left up the middle from end to end, to contain the fuel: if the clamp be large, as many of these are left as may be required. Small openings are also left between the bricks at the bottom part of the clamp, for the deposit of the cinders used for fuel, called *breeze*.* The flues are not arched over, but the bricks are overset gradually till they meet, or nearly so, at the top; layers of breeze are laid occasionally between the layers of bricks, and the *breeze* is laid thickest towards the outside of the clamp, which causes the bricks on all sides to lean slightly towards the centre: the bricks in the upper part of the clamp are set closer than those in the lower part, as they receive a great portion of heat from underneath, and do not require so much *breeze* to be distributed amongst them. When the new bricks are put in the clamp, the top is covered with dry earth or turfs, and the outside is cased with old slack-burnt bricks, called *place-bricks*; a few of these are also intermixed in the clamp. The fire is then applied to the wood in the flues, and as soon as it makes sufficient progress, the ends are stopped up with old bricks, and plastered over with clay; and the fire spreading in all directions, the clamp soon becomes one solid mass of fire, being fed by the ashes contained in the bricks themselves, as well as by the layers of breeze between them. While in this state it should be carefully watched, as in windy weather the draught will carry the fire entirely to one side: this is to be prevented by setting boards or hurdles, with straw or reeds interwoven between the splints, against the side on which the wind blows.

The quantity of fuel to be used can only be ascertained by practice, as it differs very materially in different soils, and also in the quality of the *breeze*, which is merely cinders collected with the ashes in London and other places: these are left behind when the ashes are screened, and very often contain a great deal of unprofitable rubbish. The quality and quantity of the ashes used in making the bricks is also a consideration; for if these be good, each brick is, as it were, a fire-ball, con-

* When coals are not to be had, *brushwood*, *furze*, and *timber* will serve every purpose of making bricks for hutting troops.—*Editors.*

taining material within itself sufficient not only to retain, but to increase the heat applied to it from without. If there be a deficiency in either of these cases, the bricks, instead of being hard and sound, and of a uniform yellowish grey colour, will be very tender and of a pale red colour, and of course will not bear exposure to the weather for any length of time. But although by using too small a portion of fuel the bricks are rendered of a very inferior quality, the other extreme, that of employing too much fuel, is not the less dangerous; for in that case the intense heat causes the bricks to vitrify or run together like melted glass, and when taken out of the clamp, twenty or thirty are sometimes cemented together: in this way they have the appearance of a mass of black rock, and are quite as hard.

Every clamp produces a greater or less quantity of each of these inferior descriptions, the plain bricks near the outside, and the others in the centre over the flues; but an experienced moulder, by whom the clamp is erected, knows how to reduce it to the lowest possible amount. The place-bricks are used for internal walls and other purposes where strength is not an object, and are sold at nearly one-fourth less price than stocks.

The masses of over-burnt bricks are called *burs*; and such of them as it is found impossible to separate with an iron crow-bar, are sold by the cart-load for rough foundations, or to form cascades or ornamental rock-work in gentlemen's pleasure grounds, for which they are very appropriate.

The grey-stock, when properly manufactured, has a decided preference over the kiln-brick, being, in most cases, more durable, less porous, and of a much more agreeable colour.

The kiln-brick may be said to be baked rather than burnt; and, like most other baked substances, is crusted over the outside, and not of equal hardness throughout. It is extremely difficult even for an experienced man to detect this inferiority; for whether well or ill burnt or baked, there is very little variation in the colours and outward appearances of them; but after being a few years exposed to the weather, the outer shell will drop off, and the remainder, on losing its protection, will speedily decay. It may be said that there are kiln-bricks as durable, in every way as well adapted for building purposes, as the best grey-stocks; and we in a great measure agree with the assertion, but at the same time wish to point out the danger of giving the preference to kiln-bricks, when it is almost impossible to detect the inferior ones from the sound ones, the appearance of both being so much alike.

There are certain methods of preparing earths by washing the common earths, and adding chalk thereto, by which the colour is varied from a deep gold-yellow to a very pale yellow, almost white; but our limits will not allow us to give a detail of the process. These colours are obtained without mixture in some earths, but they are much more rare than the common sort.

These bricks are termed *marls* or *malms*, and are again divided into *rubbers*, *pickings*, and *seconds*: the first are used for rubbed arches over windows and doors, and similar ornamental work, being cut with a brick-axe, and afterwards rubbed on a grit-stone.

Some of the finer sorts of kiln-bricks are also used for the like purposes.

I.

ICE.*—The action of frost has often rendered useless obstacles ordinarily of great value for defence: the capture of the Dutch fleet by the French artillery crossing the Zuyder Zee on the ice, in 1795, and the storming of Bergen-op-Zoom by the British troops crossing its wet ditches when frozen over, are among the most recent instances of this; and the disaster of the French at the Berezina, in 1812, is a proof of its power of *impeding* the passage of rivers. It is therefore of the utmost importance in warfare to foresee it effects, whether in rendering muddy roads, and even marshes or lakes, as firm as the best pavement, or in making rivers impassable by filling them with loose ice, or ice too thin to bear troops.

The *thickness* of ice required for supporting infantry in files, is about 2 inches; for cavalry and light guns, 4 inches; and for heavy carriages, not less than 6 inches: the latter should always be kept as far apart as possible. Also, if 8 inches thick, 24-pounder guns on sleighs may pass over it, or any load not causing a greater pressure than 1000 lbs. per square foot on the surface covered by the runners or skids on which it moves;† and if the ice is weak, they may have baulks secured by lashings to the tires of the wheels, for them to slide upon, so as to spread the weight over a larger surface, or lines of planks should be laid down for them to pass over.

Weak ice may be made capable of bearing even artillery in a very short time, during frost, by spreading upon it layers of straw or brushwood crossing each other, and sprinking them with water, so as to form a solid road when frozen; and if any portion of the river remains unfrozen, from the rapidity of the current, it may be made to freeze by mooring trees and brushwood so as to float in it.

When the ice is too thin for walking upon it, a man may often skate over it, which is also the most rapid mode of conveying information over ice; and ice-boats, similar to those used in Canada, might also be used for this purpose. They consist of a slight frame supported on three skates or runners, one of which serves as a rudder, and, provided with mast and sails, they tack like a ship with great rapidity directly to windward, and attain a velocity of twenty miles an hour with a fair wind.

Floating ice is very liable to destroy bridges; and its effects in rubbing against the piers, when propelled by a strong current, are amazing, tearing off the smallest projecting portions, even if of iron. To resist this, *ice-breakers* in front of the piers are indispensable; they consist of a frame supported on two rows of piles meeting each other and forming a small angle against the current: the upper surface should be planked over, and should slope upwards from the water's edge towards the top of the pier, so that the floating ice may rise over it, and thus break itself up, so as to pass harmlessly between the piers, which, if of piles or trestles, should be carefully planked over, to prevent the ice catching in them.

To *cross rivers* full of floating ice, very strong boats or canoes cut out of entire trees, are required to resist the pressure; they may be dragged over the floes (even if in motion), which are too solid to admit of breaking canals through them.

To open a communication through fixed ice, or to destroy that in the ditches of fortifications, strong barges (if possible, moved by screw-propellers) are required; their bows must be well protected with iron plates, and they should be provided with heavy beams, to be raised by ropes and let fall upon the ice in front. Saws may also

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* By Lieutenant-Colonel Bainbrigge, R.E.

† This is proved by the details relative to the transport of a 24-pounder gun over ice by the American artillery, published by the Committee of the Royal Artillery Institution, Woolwich, March, 1846.

be used if the ice is very solid, having heavy weights attached to the end under water, and the pieces of ice, when detached, can be hauled out of the water by means of ropes.

In the defence of fortifications during frost, canals, 15 feet wide at least, should be kept open along the centre of the ice covering the wet ditches, by keeping boats constantly moving along them: the earthen slopes may be rendered slippery also by pouring water over them, so as to cover them with a coating of ice.

Small barriers of ice, or the *keys* of barriers interrupting the navigation, or causing an inundation, may be destroyed by turning streams of water against certain points, so as to melt an opening, or by means of charges of powder in casks or bags fixed underneath or lodged in holes bored in the ice, and fired simultaneously: a charge of 6 lbs., placed in the centre of ice 2 feet thick, will break it up into small pieces throughout a circle of 10 feet radius.

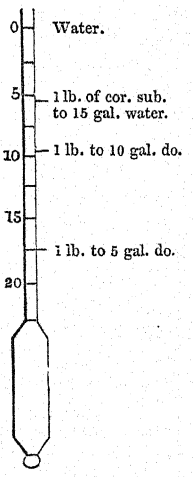
Ice and snow, well rammed together, form temporary parapets capable of even more resistance against shot than those of earth.—P. J. B.

K.

KYANIZING AND BURNETTIZING.*—KYANIZING is a simple process by means of which timber, canvas, and cordage, etc., may be preserved from the effect of dry-rot, and seasoned in a very short time. It was invented by Mr. Kyan, who obtained a patent for it, which was purchased by a Company called the "Anti-Dry-rot Company," constituted and empowered by Act of Parliament.

The timber is prepared as follows.† A wooden tank is put together so that no metal of any kind can come in contact with the solution when the tank is charged. The solution consists of corrosive sublimate and water, in the proportion of 1 lb. of corrosive sublimate to 10 gallons of water, as a maximum strength, and 1 lb. to 15 gallons as a minimum, according to the porosity or absorption of the timber subjected to the process.

HYDROMETER.



Oak and fir timber absorb nearly alike, but the domestic woods, beech, poplar, elm, etc., are more porous.

An hydrometer will mark accurately the strength of the solution, water being 0° (*vide* diagram); then, when the hydrometer sinks to 6°, it denotes that the solution contains 1 lb. of sublimate to 15 gallons of water; when it rises to 17°, 1 lb. of sublimate to 5 gallons. As a general rule, when it stands midway between 5° and 10°, the solution will be the proper strength.

The corrosive sublimate will dissolve best in tepid water.

The period required for saturating timber depends on its thickness: twenty-four hours are required for each inch in thickness, for boards and small timbers.

The timbers, after saturation, should be placed under a shed or cover from the sun

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* By the late Lieutenant-Colonel Alderson, R.E.

† See the first volume of 'Professional Papers,' Article XIX.

and rain, to dry gradually. In about fourteen days, deals and timber not exceeding three inches in thickness will be perfectly dry and seasoned, and fit for use. Large timbers will require a proportionate time, according to their thickness.

The solution may be used *ad infinitum*, as its strength is not diminished; but it will be advisable to ascertain occasionally by the hydrometer that it contains the required proportions of corrosive sublimate and water.

Professor Faraday and the late Dr. Birkbeck have, with many other scientific men, testified in the strongest manner to the efficacy of this solution. The former says, with respect to the penetration of the solution by steeping, *without* pressure, it may be tested by the application of a drop of hydro-sulphuret of ammonia, which will turn black on meeting with the mercury.

In the cube of elm, the corrosive sublimate may be traced by the above test to the depth of from $\frac{1}{5}$ to $\frac{1}{4}$ of an inch; by the test of voltaic action, from $\frac{3}{4}$ to 1 inch.

In the cube of oak, with the same test, it was found at $\frac{1}{4}$ of an inch, but irregular, and apparently followed the fissures of the wood; by voltaic action, not quite so far as in the elm.

In the cube of fir, the penetration was the least by the common test, $\frac{1}{8}$ to $\frac{1}{6}$ of an inch; by voltaic action $\frac{1}{2}$ of an inch, the turpentine in the wood probably being the obstruction to penetration.

From this testimony it is evident that when pressure is *not* used, the timber should be worked up into the form required for use prior to immersion.

The Patentees or Company, who have also the means of saturating with hydraulic pressure at their establishment, similar to that at Portsmouth Dockyard, under Sir William Burnett's process, grant licenses at the rate of 5*s*. per cubic foot internal dimensions of the tank, and sell corrosive sublimate at 4*s*. per lb.

1½ lb. is sufficient to saturate a load of timber of 50 cubic feet, at the rate of 1 lb. of sublimate to 15 gallons of water.

The process has been for several years extensively used for sleepers on railroads.

Within the last year, several of the sleepers on the South-western Railway, which had been subjected to this process, have been taken up, owing to their being decayed, particularly in the chalk districts. It is, however, stated by the Engineer that they were steeped by themselves in a hasty manner, and that he does not consider it conclusive against the process: that he has never seen any wood decayed that had been steeped by the Patentees.

It is also said that neither Kyan's, Burnett's, nor Payne's process can resist the combined effects of moisture and great heat, say 80° Fahr.

BURNETTIZING.

Burnettizing is the process by means of which timber, felt, canvas, cordage, cottons, and woollens may be preserved from dry-rot, mildew, moth, and premature decay. It takes its name from its inventor, Sir William Burnett, M.D., K.C.B., F.R.S., of the Navy, who took out a patent for it in 1837.

It consists in immersing the various substances above enumerated, in a solution of chloride of zinc and water in a wooden tank,* in the proportion of 1 lb. of chloride of zinc to 4 gallons of water for wood, and 1 lb. of the chloride to 5 gallons of water for the remainder of the articles, with the exception of *felt*, which requires 1 lb. of the chloride to *two* gallons of water.

Three-inch deals require to remain in the tank or cistern *six days*, and all other

* See the first volume of 'Professional Papers,' Article XIX., on Anti-Dry-rot.

woods in the same proportion, or two days per inch. They are then taken out and put under a shed, on their ends, to dry; and require for this purpose from fourteen days to three months, according to the thickness of the wood, when they are fit for use.

The timber should be reduced to the scantling required for use before it is subjected to this process.

Canvas, yarn for cordage, cottons, and woollens, require to be suspended in the solution for forty-eight hours.

The process, however, with respect to timber, is much more expeditiously and effectively done by hydraulic pressure in Her Majesty's Dockyard at Portsmouth, where large quantities of timber, etc., are prepared for the use of the Royal Navy at the various dockyards in England, particularly for ships' magazines.

There is a large wrought-iron tank, 52 feet in length and 6 feet in diameter, with a door 2 feet 6 inches × 2 feet at each end for loading.

Timber of all sizes and descriptions is put into this cylinder, which contains about *twenty* loads. As soon as it is filled, and the doors well secured both against external and internal pressure, the air is exhausted in the cylinder, and also in the timber, by means of an air-pump worked by a small rotatory engine of ten-horse power, on the Earl of Dundonald's principle, until the barometer stands at 27°. The valve leading to the air-pump is then shut, and the cock of a pipe leading from the tank filled with the solution, to the cylinder, is turned; the solution rushes into the cylinder to fill up the partial vacuum, and about half fills it, when the cock is turned, and the air-pump again set to work until the barometer stands at 27½°, when the same process is repeated, and the cylinder nearly filled with the solution.

A pressure of 150 lbs. per square inch is then obtained by means of a Bramah forcing-pump, connected with an iron copper or reservoir, filled with the solution, and communicating with the cylinder by means of a pipe. This is worked by hand until a valve placed on the top of the cylinder, and loaded to the required gauge, begins to lift.

The timber is then left in the cylinder, subject to this pressure, for *eight hours*, which is considered sufficient for the largest logs, even in a rough state. The solution being then drawn off into the tank, and the timber taken out of the cylinder, it is re-loaded, and the process repeated: the same solution is used for two months, when fresh is prepared.

The same process for drying the timber thus saturated is adopted, as before stated. Canvas, felt, and yarn, etc., are not subjected to pressure.

The felt* is used as a lining to the magazines of men-of-war, between two thicknesses of wood; also to cover over the steam boilers of steam ships: it is said to be rendered much less liable to combustion by the process.

It is also stated that in tropical climates, more especially in Africa, the saturated canvas† has stood the climate, when the unprepared, under similar circumstances has rapidly decayed.

Both Burnettizing and Kyanizing offer great advantages to the Engineer:

1st. Wood of every kind is rendered more durable, and is rapidly seasoned.

2ndly. It brings into general use larch, poplar, and a variety of other indigenous woods, as well as American pine, etc., which, without the process, from being liable

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* An India-rubber felt, composed of caoutchouc and cork, is also used.

† Some experiments were tried in Dublin in 1845, 6, 7, under the direction of the Commanding Royal Engineer, on *sand-bags* which were Kyanized and Burnettized by way of judging if the sand-bags could be used a second time, but without success: they were found in all cases in a state of decay.—*Editors.*

to rapid decay, and being much inferior to Baltic timber, are seldom used in public buildings.

To the Military Engineer, these inventions offer still greater advantages. He is frequently called on, in distant colonies, to construct block-houses, stockades, bridges, and barracks, where the only material to be had in abundance is the tree standing in the forest: to him a few pounds of either ingredient would be invaluable, by enabling him to season and render durable the timber a few days after it was cut down; and thus provide him with the ready means of rendering a distant post tenable in a short time by a small body of men, with the satisfaction of knowing that the work thus hastily erected was of a permanent nature.—R. S. A.

L.

LABORATORY—A department connected with the Royal Artillery entrusted with the manufacture of combustible and other substances for military purposes, such as blank and ball cartridges for small arms, cartridges for every description of ordnance, percussion caps, rockets, and all *stores* of a similar character.

The laboratory department is likewise entrusted with the conservation, packing, re-storing and supply of all gunpowder to the several Naval and Military departments, and is under the management of Officers of the Royal Artillery specially appointed to that duty.

Officers of Artillery, as well as the non-commissioned Officers and gunners, are instructed in the *laboratory* duties, and carefully taught the manipulation and manufacture of laboratory stores: for the nature, composition, and manufacture of these, see the Article "Pyrotechnics, Military."—G. G. L.

LEVELLING*—The art by which we determine the relative height of any number of points.

The height of a point is the vertical distance to which it is elevated or depressed, as compared with the *true general surface of the earth.*

The earth is in form a spheroid. On land we can nowhere trace its true geometric surface; but the sea, when at rest, presents everywhere a very near approximation to it, and hence the *level of the sea* has been assumed as the standard to which all heights are referred.

The absolute height, then, of any point is its vertical distance from the *level of the sea:* the relative height of two or more points, commonly called their *difference of level,* is the difference of those vertical distances.

A *true level* is any surface or line which is parallel to the true geometric surface of the earth; every true level must, therefore, necessarily present a curve everywhere perpendicular to the direction of gravity. It is a beautiful property of fluids that in every situation, when at rest, their surface will present a *true level.*

All points situated within the same true level are evidently at the same height.

One point is said to be higher or lower than another, according as a true level traced through it passes above or below that point; and the vertical distance at which it so passes, is the measure of their relative height.

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* By Captain Laffan, Royal Engineers.

In theory, levelling is extremely simple. It consists in tracing through space a series of level surfaces, and finding their intersections with vertical lines passing through the points whose *relative height* we wish to ascertain.

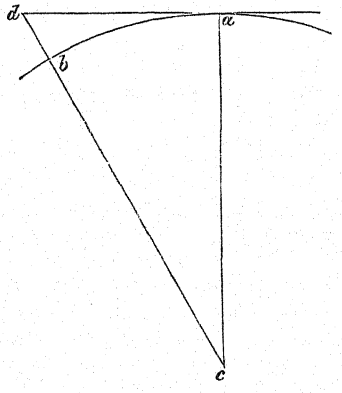
Thus, in order to determine the relative height of two points, we establish at some convenient spot in their neighbourhood a truly level surface, and with the eye, assisted, when necessary, by optical instruments, we endeavour to trace the continuation of that surface till it intersects vertical lines passing through the two points. The vertical distances from each point to its corresponding intersection will give the difference of level between that point and the observer's eye; and the difference or the sum of those vertical distances, according as the points are on the same or on different sides of the level surface, will give the difference of level sought.

In practice however, the simplicity of the theory is disturbed by two sources of error, called th errors of *curvature* and *refraction*.

The first arises from the spheroidal form of the earth, in consequence of which all true levels must necessarily be curves; whereas we can only trace horizontal lines or planes tangent to those curves at the points whereon we stand. These we call the "apparent," to distinguish them from the "true" levels.

In thus substituting the apparent for the true levels, we evidently give rise to an error in the observation, the effect of which is to *depress* the apparent place of any distant point. This effect increases the further our observations extend: within short distances of 200 or 300 yards, it is so small that except in extremely accurate levelling it may be overlooked; but for greater distances, it is necessary to apply a correction. (See fig. 1.)

Fig. 1.



If we suppose *a b*, in the annexed figure, to represent a portion of the earth's surface, *a* the point where the observer stands, and *b* the point observed, *c* the centre of the earth, and *a d* a horizontal line or "apparent level;" then *b d* is the error of curvature due to the distance *a b*, and it is evidently the difference between the radius and secant of the arc *a b*. If we call this difference x, the arc or distance D, the tangent or apparent level t, and the radius r, we have the following equation:

$$(r + x)^2 = r^2 + t^2,$$

from which $x\,(2r + x) = t^2$; and as the quantity (x) must always be extremely minute when compared with the earth's radius, we may substitute $2\,r$ for $(2r + x)$, and, in the same way, we may substitute D^2 for t^2, when we shall have

$$2\,r\,x = D^2,$$

$$\text{whence } x = \frac{D^2}{2\,r}.$$

It appears, then, that the error increases as the square of the distance between the observer and the point observed. Assuming the mean diameter of the earth to be 7916 miles, we find the correction for curvature for one mile to be 0·667 of a foot, or 8·004 inches. A formula easily remembered is, that the correction in feet is equal to $\frac{2}{3}$ the square of the distance in miles; or that the correction in inches is equal to $\frac{1}{800}$ the square of the distance in chains.

The second source of error, *terrestrial refraction*, has a contrary effect to that of

curvature, inasmuch as it tends to elevate the apparent place of any distant point. It varies in amount according to the state of the atmosphere, but, as a general rule, it may be assumed equal to $\frac{1}{7}$ the error of curvature; and as it acts in a contrary direction, it must be subtracted from it. The correction, in feet, for the two combined will be $\frac{4}{7}$ the square of the distance in miles.

These corrections are very troublesome, and, whenever it is possible, it is desirable to do away with the necessity for applying them. This can generally be done by choosing, as a point to level from, some spot equidistant from the points we wish to observe. The errors both of curvature and refraction then compensate themselves, for they act equally both ways. In the series of observations, however, required to level a long line, instances will frequently occur in which it is impossible to observe from a point equidistant from the other two; but even in this case the errors may be compensated in the next observation, by making the point of observation equally eccentric the opposite way.

The instruments made use of in levelling operations are founded upon two principles.

1st. Every line or plane perpendicular to the direction of gravity, is horizontal, or apparently level.

2nd. The surface of every liquid at rest being a true level, all lines or planes tangent to such surfaces will be apparent levels.

On the first of these is founded the common mason's level and all reflecting levels.

The second is the principle of the simple water level and of the various descriptions of spirit levels now in use.

The common mason's level is too well known to need a description; it will do for rough work and short distances, but should never be used whenever a superior instrument can be procured. In military reconnaissances however it might be turned to some account, by adding a graduated arc described from the summit as a centre, and numbered on each side from the centre line. On applying it then to any slope, the string would mark on the arc the exact angle of inclination we desire to know. (See figs. 2 and 3.)

Fig. 2.

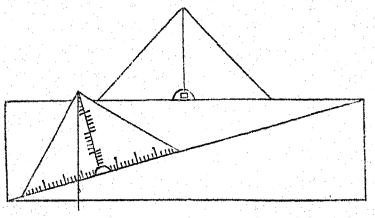
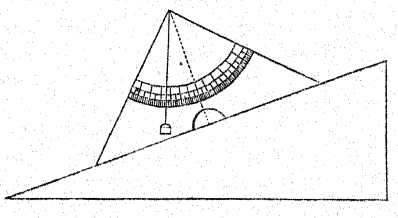


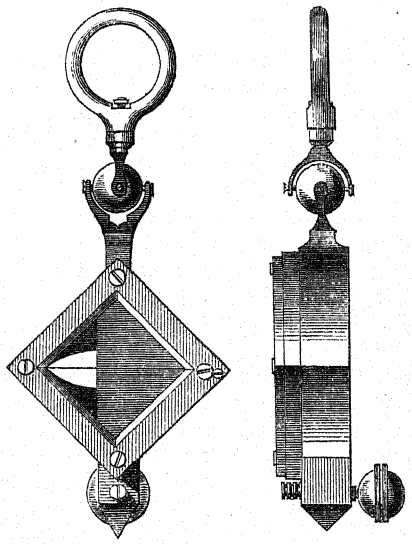
Fig. 3.



The reflecting levels consist of a small piece of looking-glass set in a metal frame,

and suspended from a point so adjusted that the plane of the glass shall be always vertical. It is evident that when we see the reflection of our own eye in the mirror, the line from the pupil to its reflected image must be perpendicular to the plane of the glass, and therefore to the direction of gravity. By shifting the instrument, therefore, we have the means of tracing any number of horizontal lines. Reflecting levels are beautiful in theory, and very portable; but in practice they are not susceptible of great accuracy. They are very good for a military reconnaissance. (See fig. 4.)

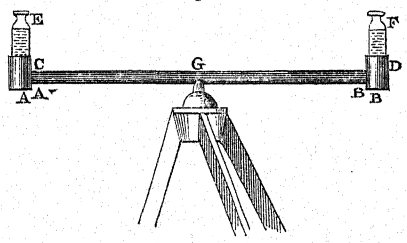
Fig. 4.



The water level is generally used for filling up the details of more extended observations, and for all operations at short distances, where great accuracy is not required. It is a very convenient instrument, easily made, and having the great advantage of never getting out of adjustment.

The water level is peculiarly adapted to the tracing of contour lines, an important branch of military surveying; and as it may prove of service to military men where superior instruments cannot be procured, the following description and sketch are annexed, to enable any one to construct one for himself with no further aid than that supplied by such common workmen as are to be found in every village. A B is a hollow tube of brass or tin, 3 feet long and ½ an inch in diameter; the ends soldered into other short tubes, C and D, of larger diameter, to receive the small bottles E and F, the bottoms of which have been cut off by tying a piece of wet string round them when heated. The bottles are fixed in the tube with putty or white lead. G is a sort of vertical axis, soldered on to the tube, and working in a cylindrical metal socket fixed to any kind of portable stand or frame. When the instrument is required for use, the tube is filled with water till it reaches nearly to the necks of the bottles, and these are then corked, for the convenience of carriage. On setting the instrument up, care should be taken to bring the tube as nearly as possible level by the eye, and the corks being then withdrawn, the water will occupy precisely the same level in both bottles, thus giving us the means of tracing a horizontal line in whatever direction we may turn the tube. The bottles should be an inch in diameter, and of rather

Fig. 5.



stakes, out of reach of disturbance in the progress of the works, may also be driven in at about every 10 chains, and the level of a cut upon each being noted, will be found very useful for reference after the breaking of the ground.

A form of field-book is appended. It will be seen on reference to it, that generally at each setting up of the instrument, the levels at several pickets may be obtained; and, except in rapidly falling ground, this will usually be the case. Some care is necessary in setting up the instrument advantageously, to effect this; and it is to be remembered, that so far as the observations extend from the same station, the reading of the last forward sight is to be entered as the next back one.

From the reduced levels, the working section is to be laid down, the total heights from the datum line being employed as shown in Plate II. The total height to the surface of the ground and the fixed altitude of any one point on the formation level being given, and the distances and ratio of inclination being determined, the depth of cutting or height of embankment at each point is directly and simply obtained.

This will appear clear on reference to the section, the horizontal scale for which is 5 chains to 1 inch, and the vertical 30 feet to 1 inch, which will be generally found sufficiently large for all purposes.

In connection with railway levelling is the setting out the side widths. When the ground does not fall transversely to the line, this is a very simple operation,—the half width of the railway + the depth of cutting or height of embankment, multiplied by the ratio of their slopes, giving the distance to be set out from the centre line: when it does fall transversely, the degree of slope may be obtained when getting the centre levels, and entered in columns prepared for it in the field-book (see form of field-book). It will be necessary, however, that the side levels should be taken at some constant distance, say 50 or any other convenient number of feet. The half-width may then be calculated from the formula

$$\frac{\sqrt{H^2 + (B + C\,r)^2} \times \left(C + \frac{B}{r}\right)}{C + \frac{B}{r} + H},$$

in which

C = depth of cutting or height of embankment.

B = half width of railway.

r = ratio of slopes.

H = diff. of height between centre and side levels at computed half-widths.

Due regard must be paid to the sign of H.

An expeditious practical method of setting out the half-width at once on the ground is as follows:* the half-width due to the several depths or heights on a level transverse section are computed and entered in a field note-book; the levelling instrument being then set up on the ground in a position convenient for the purpose, the difference of level between the centre and a point somewhat nearer than the computed distance, if the ground is falling, or further off, if rising, is obtained: this difference, multiplied by the ratio of the slope, gives a quantity to be added to or deducted from the computed half-width, at which corrected distance, the staff being again applied, and the difference of level taken, by repeating the calculation, a second approximation to the true point is made, which will in practice be found sufficiently exact.

The form of note-book is given below the form for the working section field-book.

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* Described in Simms's 'Treatise on Levelling.'

The method to be pursued, and the form of field-book, do not differ from those described for running trial sections; but a greater degree of minuteness is required, and bench-marks should be established as often as fit objects and positions occur for making them on. These bench-marks are merely horizontal grooves (in this form usually ⊼) cut in some permanent object, as a mile-stone, the masonry of a bridge or other structure, a gate-post, the trunk of a tree, etc.; and their purpose is to serve as a basis for ulterior operations, or for testing the accuracy of the work by running check levels. In running check levels (and generally they are necessary), all that is required being the difference of heights, the distances need not be measured; and it is usual to pursue the most convenient route in connecting the bench-marks. Thus, on the plan (Plate I.), in order to check the difference of level between the bench-marks on the boundary stone at C and on the building at B, the road by the point A would be followed.

In the field-book for check levels, columns for the back and forward sights, and a column for remarks, are all that are required.

The section is now to be laid down on the plan according to the system termed "Sectio-Planography," required by the Standing Orders of Parliament, exhibiting the several cuttings and embankments; the cuttings being above and the embankments below the line marking the centre of the proposed railway. This system is shown on the plan (Plate I.) by the thin dotted line *a a a*.

A Parliamentary section is also to be prepared, the scale for horizontal distances being required to be not less than 4 inches to 1 mile, whilst the vertical heights must be to a scale not less than 100 feet to an inch.

In the plan above referred to, with its corresponding sections, the scales are 6 inches to the mile for the horizontal distances, and 80 feet to 1 inch for the heights.

It is also required that a line shall be drawn on the section, representing the proposed upper surface of the rails; and also that at each change of inclination the height in feet and inches above a given datum level shall be marked; and that the rates of inclination shall likewise be shown. These points will be made clear by reference to the section (Plate I.).

The datum level generally referred to in this country, is the Trinity high-water mark at London Bridge; other points more locally convenient may be referred to, but it is of general utility that all should be reduced to the same standard level.

The "Standing Orders" further require that the height of the proposed railway under or over any turnpike-road, navigable river, canal, or other railway, shall be marked at the crossing; and also that any proposed change in the existing surface level of the river, etc., shall be shown. (See Transverse Section, Plate I.)

Also, that where tunnelling is substituted for cutting, or arching for embanking, it shall be marked on plan and sections; and also that no deviation from the levels on the plan approved by Parliament, shall be permitted to exceed in any place 5 feet in open country, or 2 feet in passing through towns, without consent of the owners, trustees, or commissioners, as the case may be: and it is further decreed that no increase in inclination shall be made in any place to an extent exceeding 3 feet in 1 mile.

The sanction of the Legislature for the construction of the proposed railway having been obtained,—prior to entering upon the execution of the works, a contract or working section must be prepared. For this purpose, on the centre line accurately staked out, pickets should be driven in at each chain's length, and at each of them, as well as at other important points, the height of the ground obtained by levelling. These pickets should all be numbered, and every 5th or 10th one being a little larger, may conveniently for reference be painted red, the others being painted white. Side-

Bearing, or Angle of Direction.	Measured Distance, Chains.	Rise.	Sights.		Fall.	Reduced Level.	Remarks.
			Back.	Forward.			
						150·00	Bench-mark on plinth
			3·44	6·72	3·28	146·52	of church: N. E.
S.E.	5·83	5·13	8·72	3·59		151·65	Angle assumed 150
25·030°	13·21	9·50	11·94	2·44		161·15	feet above datum
	16·54	7·63	10·65	3·02		168·78	level.
	18·00	8·11	9·89	1·78		176·89	
	18·36	12·22	14·32	2·10		189·11	Centre of road.
	23·10	8·47	11·66	3·19		197·58	Top of bank.
	29·00	7·20	9·78	2·58		204·78	
	36·59	4·53	7·24	2·71		209·31	
	43·20	6·33	8·86	2·53		215·64	
	44·00		1·23	11·53	10·35	205·34	Crest of ridge.
	45·08		0·98	12·76	11·78	193·56	Edge of brook.
S. by E.	45·90	8·51	12·76	4·25		186·07	Top of bank of brook.
267·15°	46·70	2·10	5·37	3·27		188·17	
	50·00	3·35	6·42	3·07		191·52	
	59·33	6·53	8·25	1·72		198·05	
	65·45	6·33	7·77	1·44		204·38	
	70·00	4·39	6·39	2·00		208·77	
			2·00	3·11	1·11	207·66	Bench-mark on gate-
	77·15	6·08	8·91	2·83		213·74	post at fork of lane.
	82·30	4·72	5·99	1·27		218·44	
	85·45		2·40	5·80	3·40	215·06	
	90·50		1·17	8·29	7·12	207·94	
		111·13	166·14	92·00	37·04		
		37·04	92·00				

Trial sections may also be run with great expedition, and with considerable, though less accuracy, by means of the theodolite. Though it is desirable that the instrument should be in good working order, it is essential only that the adjustments of the line of collimation and of the transverse level should be perfect.

The method of proceeding is, to set the instrument up at the point of each general change of inclination, and setting a vane on a staff to the height of the levelled axis of the telescope (which may be made constant), to send it forward to the next point the relative level of which is required. The horizontal reading and angle of elevation or depression being then noted, and the distance measured to the surface of the ground, the horizontal distances and differences of level are readily obtained, making due allowance for curvature and refraction.

The other lines of trial sections having been also run (and it is desirable that they should all close on, as well as start from, the same point, that they may form a check on each other), in order to compare their relative merits, the sections should be laid down together on the same piece of paper, and with reference to the same plane of comparison, which it is convenient to assume at some distance below the lowest point to which the section descends. The sections may be coloured differently, the more readily to distinguish them. A scale sufficiently large on which to lay them down will be 4 inches to a mile for the distances, and 80 feet to an inch for the heights.

From these data the selection of the line to be adopted is to be formed, and in coming to the ultimate decision, on which the success of the scheme so much depends, the most careful deliberation is called for.

The line determined on is now surveyed; and following as near as possible the proposed centre line, a new series of levels is to be run.

unnecessary to move forward the second barometer; but when this limit is exceeded, it ought to be brought forward at the completion of a day's work, and a fresh start for the next day's work made from the last visited point.

Subjoined is the form of field-book recommended for barometrical observations:—

Date and Hour.	No. of Station.	Reading of Barometer.	Thermometer.		Deduced difference of Level.	Remarks.
			Attd.	Detd.		

The lines between which a comparison shall be instituted having been decided on, the process of levelling to obtain their sections is now to be proceeded with.

The instruments required are, a levelling instrument (Troughton's or Gravatt's pattern is generally preferred), a levelling staff, an iron tripod rest, and a 100-feet or Gunter's chain.*

It is essential that the instruments should be in adjustment, and the chain correct, or its error noted.

Taking then one of the lines to be tried, the course which it is to follow having been clearly pointed out, and a first portion laid out straight, or it may be curved, the levelling instrument is to be set up in a convenient position for taking the back and forward sights, and a general point of reference being established (which should be a bench-mark on some permanent object), the levelling staff is to be applied to the point of reference, and its reading noted and registered. The staff is then to be moved on to the forward station, where the reading being noted, and the distance measured and entered, the levelling instrument is carried forward; and the last forward now becoming the back station, the process is repeated until the section is completed. It is not necessary that the instrument should be set up in the line of section; it is generally more convenient that it should not be so; but it is most desirable that it should be as nearly as possible at equal distances from the back and forward stations.

In taking trial sections, it is to be observed, that minute accuracy in noting every trifling undulation would be a mere waste of time, as it is very improbable that the centre line of the intended railway will be followed; and a deviation of but a few feet from it may make a considerable difference in the levels. The levels of the crossings of all roads and streams, as well as of each change of general inclination, should however be observed, and the distances of the points apart limited to the range of the instrument, about 5 chains, beyond which the liability to error increases.

The following is the form of field-book recommended for trial sections. It appears sufficiently clear to render explanation unnecessary.

* Where the object of the measurement is confined to obtaining sectional areas and content, the 100-feet chain is much the most convenient; but where superficial areas are required, Gunter's chain is preferable. A Table of Equivalents will be found very useful in reducing the measurements, when either chain is used for both purposes.

Example.—Boiling point at upper station . . . . . 185° = 14548
Barometer at Calcutta (at 32°) 29·75 in.
Logar. diff. = 1·47712 − 1·47349 = 00363 × 0006 = 218

Approximate height 14330
Temperature, upper station, 76° } 80° = multiplier . . 1·100
Ditto lower, 84° }
Correct altitude 15763

Assuming 30·00 inches as the average height of the barometer at the level of the sea (which is however too much), the altitude of the upper station is at once obtained by inspection of Table I., correcting for temperature of the stratum of air traversed by Table II.

MEMORANDA ON RAILWAY LEVELLING.*

The circumstances which may influence the selection of the route to be followed in the construction of any projected line of railway may be various; but in general, with a due regard to local and geological considerations, it will be mainly determined from the lines of section obtained by levelling and linear measurement.

As a measure preliminary to the selection of trial lines of section, a careful and minute reconnaissance of the country to be traversed, is indispensable. Where maps so full in detail and so accurate in representation of feature as the Ordnance maps of England (scale 1 inch to a mile) are procurable, this proceeding is greatly facilitated; and according to the amount of assistance derivable from such a source, so will the tedium of this stage of operations be increased or diminished.

The watercourses and mountain ranges, or ridges in more level countries, will necessarily form the grand guide in this inspection. Much assistance may however be derived, especially in a mountainous country, and where the distance between the termini of the proposed railway is considerable, from barometrical measurements,† which may frequently render it unnecessary to make trial of a line which to the eye might appear to be within the limits of comparison; and even possibly, in a short line, might lead to the determination of the course to be adopted, without further trial. When the barometer is thus brought into requisition, in order to obtain the best results, a means of direct comparison should be constantly maintained with the initial point, which will of course be one of the termini of the proposed line. To this end a second barometer should be provided: both should be set up together, and their readings compared; and whilst the first, or travelling barometer, is carried forward, the second should be left in charge of an assistant, to be noted every quarter of an hour; then, at each point the altitude of which is required, the travelling barometer being set up, the time and readings are to be noted, and when the scale of the guide map admits, as the Ordnance map will do, a point being marked on it indicating the station and a number against it, a corresponding number must be entered in the field-book. Where the aid of such a map is not obtainable, a sufficient description of the station must be written, and its bearing and distance, as well as can be ascertained from previous stations, or from known fixed points, also given.

When the distance between the extreme points of the ground reconnoitred is not more than twenty miles and the tract of country is not mountainous, it may be

* By Lieutenant-Colonel M'Kerlie, R.E.

† See also in this article ("Levelling"), Colonel Sykes's application of the common thermometer to determine heights.

TABLE II.

Table of Multipliers to correct the Approximate Height for the Temperature of the Air.

Temperature of the Air.	Multiplier.	Temperature of the Air.	Multiplier.	Temperature of the Air.	Multiplier.
32°	1·000	52°	1·042	72°	1·083
33	1·002	53	1·044	73	1·085
34	1·004	54	1·046	74	1·087
35	1·006	55	1·048	75	1·089
36	1·008	56	1·050	76	1·091
37	1·010	57	1·052	77	1·094
38	1·012	58	1·054	78	1·096
39	1·015	59	1·056	79	1·098
40	1·017	60	1·058	80	1·100
41	1·019	61	1·060	81	1·102
42	1·021	62	1·062	82	1·104
43	1·023	63	1·064	83	1·106
44	1·025	64	1·066	84	1·108
45	1·027	65	1·069	85	1·110
46	1·029	66	1·071	86	1·112
47	1·031	67	1·073	87	1·114
48	1·033	68	1·075	88	1·116
49	1·035	69	1·077	89	1·118
50	1·037	70	1·079	90	1·121
51	1·039	71	1·081	91	1·123

Enter with the mean temperature of the stratum of air traversed, and multiply the approximate height by the number opposite, for the true altitude.

When the thermometer has been boiled at the foot and at the summit of a mountain, nothing more is necessary than to deduct the number in the column of feet opposite the boiling point below, from the same of the boiling point above: this gives an approximate height, to be multiplied by the number opposite the *mean* temperature of the air in Table II., for the correct altitude.

		feet.
Boiling point at summit of Hill Fort of Púrundhur, near Púna	204·2°	= 4027
Boiling point at Hay Cottage, Púna	208·7	= 1690
	Approximate height	2337
Temperature of the air above	75°	
Ditto ditto below	83	
	Mean, 79o = multiplier .	1·098
	Correct altitude	2566

When the boiling point at the upper station alone is observed, and for the lower the level of the sea, or the register of a distinct barometer is taken, then the barometric reading had better be converted into feet, by the usual method of subtracting its logarithm from 1·47712 (log. of 30 inches) and multiplying by ·0006, as the differences in the column of "*barometer*" vary more rapidly than those in the "*feet*" column.

TABLE I.

To find the Barometric Pressure and Elevation corresponding to any observed Temperature of Boiling Water between 214° *and* 180°.

Boiling Point of Water.	Barometer, modified from Tredgold's Formula.	Logarithmic Differences for Fathoms.	Total Altitude from 30·00 in., or the Level of the Sea.	Value of each Degree, in Feet of Altitude.	Proportional Part for One-tenth of a Degree.
			Feet.	Feet.	Feet.
214°	31·19		−1013		..
213	30·59	00·84·3	507	−505	..
212	30·00	84·5	0	507	..
211	29·42	84·9	+509	+509	51
210	28·85	85·2	1021	511	..
209	28·29	85·5	1534	513	..
208	27·73	85·8	2049	515	..
207	27·18	86·2	2566	517	52
206	26·64	86·6	3085	519	..
205	26·11	87·1	3607	522	..
204	25·59	87·5	4131	524	..
203	25·08	87·8	4657	526	..
202	24·58	88·1	5185	528	53
201	24·08	88·5	5716	531	..
200	23·59	88·9	6250	533	..
199	23·11	89·3	6786	536	..
198	22·64	89·7	7324	538	54
197	22·17	90·1	7864	541	..
196	21·71	90·5	8407	543	..
195	21·26	91·0	8953	546	..
194	20·82	91·4	9502	548	55
193	20·39	91·8	10053	551	..
192	19·96	92·2	10606	553	..
191	19·54	92·6	11161	556	..
190	19·13	93·0	11719	558	56
189	18·72	93·4	12280	560	..
188	18·32	93·8	12843	563	..
187	17·93	94·2	13408	565	57
186	17·54	94·8	13977	569	..
185	17·16	95·3	14548	572	58
184	16·79	95·9	15124	575	..
183	16·42	96·4	15702	578	..
182	16·06	96·9	16284	581	..
181	15·70	97·4	16868	584	..
180	15·35	97·9	17455	587	59

The fourth Column gives the Heights in Feet.

TABLE OF ALTITUDES.

Year.	Date.	Names of Places.	ALTITUDES DEDUCED FROM 1	2	3	4	5	6	7	8	9	10	11	12	13	14
			Jones's Bar. No. 2, with assumed pressure of 30° in., and mean temp. 82° at the level of the sea.	Cary's Barometer, No. 2, ditto ditto.	Corresponding observations with Captain Jervis's Gilbert's Bar. and Cary's No. 2.	Corresponding observations with Dr. Walker's Gilbert's Bar. and Cary's No. 2.	Corresponding observations with Capt. Jopp's and Cary's Bar. No. 2.	Corresponding observations with Cary's Bars. Nos. 1 and 2.	Corresponding observations with Cary's Bar. No. 1, and Jones's No. 2.	Heights by boiling temperatures, Therm. 1, by the Madras Tables.	Heights by boiling temperatures, Therm. 2, by the Madras Tables.	Heights by boiling temp. by Lieutenant Robinson's Tables, Indian Navy.	Heights by boiling temperatures, by Tables of James Prinsep, Esq., Calcutta.	Difference between the means of *all* the boiling temperatures and barometric corresponding observations.	Mean of corresponding observations by Barometers.	Mean of all the boiling temperatures.
1827	23 May ...	Highest point, Hill Fort of Púrundhur	4588	4599	... ..	.....	.....	*4471	4528	4536	4553	4415	4427	−16	4499	4483
1827	10 May ...	Singhur Hill Fort	4199	4180	.....	.....	.....	*4211	4170	4341	4220	3927	3928	−86	4190	4104
1828	15 May ...	Temple at Bíma Shunkur .	.....	.....	.....	.....	*3090	.....	.....	3037	3037	2992	2991	−71	3090	3019
1825 1827	6 March 11 May .	Karleh, Cave Temple	2493	2652	.....	.....	.....	*2530	.....	2693 2526	2646 2526	2468	2478	+27	2530	2557
1827	23 May ...	Highest Point of Púrundhur above Púna ...	2697	2681	.....	.....	.....	*2648	*2650	2661	.....	2539	2566	−61	2649	2588
1828	9 Feb. ... 3 April .	Pait on the Yail River ...	.....	.....	*2478 *2493	.....	*2470	.....	.....	2494	2494	2480	2484	+8	2480	2488
1828 1829	.....	Temple in the Hill Fort of Hurichundurghur .	3972	3931	3845	*3922	†3871	*3887	3935	3840 3887	3869 3887	3824	3788	−46	3892	3846
1829	11 to 17 Dec. ...	Source of Kristna River at Mahabuleshwur ...	.....	.....	.....	*4496 *4503	... ..	.....	.....	†4498	†4556	†4422	†4425	−24	4499	4475
1828	27 April .	Pokrí	.....	.....	.....	.....	*3197	.....	.....	3194	3194	3185	3141	−19	3197	3178
1828	6 April ...	Kullumb, on Goreh River	.....	.....	2043 2027	.....	*1995	.....	.....	1971	2000	1988	1986	−36	2022	1986
1825 1826 1827 1828 1829	.....	Púna, Hay Cottage	.....	.....	1810 1820	*1810	*1837	*1823	.....	Means 1883	1897	1876	1861	+59	1820	1879
1828	16 Feb. ...	Downde, on the Bíma River	.....	.....	.....	.....	1623	.....	.....	1591	1591	1567	1575	−41	1623	1582
1828	29 Oct. ...	Sasswur, above Púna	.....	.....	.....	592	.....	.....	.....	†514	†456	.....	.....	−107	592	485

* The heights most relied on.

† Boiling temperatures determined by Dr. Walker.

in measuring heights where great accuracy is not required; and it will be recollected that what is usually looked upon as a difficult and troublesome operation with barometers, will be attainable by any person who carries with him a couple of thermometers,* the requisite tin pot, and the Tables, and who is master of the simplest rules of arithmetic.

Of the three Tables in my possession, I have chosen Mr. Prinsep's, from their perspicuity and the facilities they offer for the conversion of boiling temperatures into heights with very little trouble; but a glance over the figures in my Tables of Altitudes will show that the Tables are susceptible of considerable improvement, for, with two exceptions, all the heights deduced from Mr. Prinsep's and Lieutenant Robinson's are much below those determined by simultaneous observations with good barometers; and I join with Mr. Prinsep in expressing a hope that every traveller boiling his thermometers will at the same time, if he possess a barometer, make a record of its indications, and thus render essential service to physics by fixing so many points on the scale of the elastic tension of steam at different temperatures.

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* SEVENTEENTH MEETING OF THE BRITISH ASSOCIATION.

"*Barometrical Levelling in the Madras Presidency by General Cullen, with Observations by Colonel Sykes.*

"Colonel Sykes exhibited and explained two maps constructed by Gen. Cullen, of the Madras Artillery, comprising five sections of country, showing the relative levels by barometrical observation at distances ranging from 10 to 20 miles: one section of about 1170 miles—another being a road distance of 543 miles. The second map contained three sections,—one of 265 miles, another of 280 miles, and a third, from Madras to Arcot road, a distance of 293 miles. A third map gave barometrical sections from Madras to Bellary, on a line about W. N. W. 244 miles; and from Bellary to Jelalamacul, on a line about W. and S. 156 miles. This map, without pretending to be a complete geological section, showed the prevailing rocks on the route. Associated with the sections, were notices of the climate and mortality at most of the stations, comprising the maxima, minima, and mean pressure of the barometer for some years; the maxima, minima, and mean indications of the thermometer; the falls of rain; the nature of the monsoons; and the sickness and percentage mortality of the European and Native troops. The whole of these laborious results indicated no ordinary industry and judgment. *Colonel Sykes's* object in exhibiting the sections was, to call the attention of Railway Engineers to the use of the barometer as the precursor of the theodolite, in determining the general levels of a country with a view to the selection of lines. He suggested also that geologists might use the barometer to fix the heights above the sea of the strata described. He stated that in the Tropics the moderate oscillations of the barometer admitted of levels being determined with some accuracy, even when the instrument was used independently; but that when the instrument used had been previously compared with the standard barometer, and that contemporaneous observations were made, he could testify, from his own experience, that a height so determined might not differ ten feet when re-tested and re-observed after a lapse of years."—*Athenæum*, July, 17, 1847.

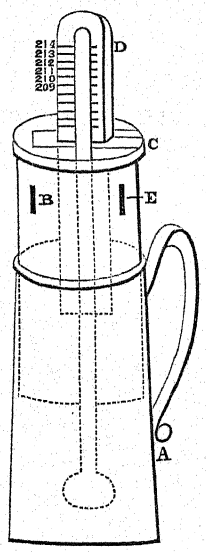
(the only satisfactory way to ascertain heights not taken trigonometrically), approximate sufficiently near for all practical purposes, where great accuracy is not desired. These Tables however differ slightly from each other.

The Table which first came into my hands appeared anonymously in the 'Madras Gazette' for 1824. In 1826, an able friend, Lieutenant Robinson, of the Indian Navy, who entered warmly into my views to determine heights by common thermometers, thought he could improve upon the table I was using, and accordingly made a new computation. The third Table came under my notice much more recently than the two former: it is computed by Mr. James Prinsep, of Calcutta, Secretary of the Asiatic Society of Bengal, a gentleman distinguished for his scientific research. He published it in the Journal of the Society. To admit of a just estimate being formed of the value of these Tables; of the value of corresponding barometrical observations, made with due precautions, although with different coadjutors and different instruments; of the value of barometrical observations, with an assumed pressure and temperature, at the level of the sea; of the value of thermometrical compared with barometrical observations,—out of many hundred heights determined in various ways, I have taken many at random (the number, it appears, is eighty-eight), and I have put them into juxtaposition in a tabular form. In thermometric heights, the elements at the level of the sea were, a boiling temperature of 212° Fahr. and a mean temperature of the air of 82°. The *assumed* pressure in heights determined barometrically, without corresponding observations, was 30 inches; mean temperature 82°. In looking over the tabulated results, I was a good deal surprised to find that in no instance, by whatever method determined, do the barometric differences in height exceed 127 feet, and this only by comparing the highest indications with an assumed pressure with the lowest indications of corresponding observations. It will be seen that the various Tables for determining heights thermometrically, with certain exceptions, do not differ very *materially* in their results from each other, nor from corresponding barometric observations; the formulæ on which they are founded may therefore be considered, on the whole, sufficiently accurate for the present state of our knowledge.

Lieutenant Robinson's and Mr. Prinsep's Tables give close approximations to each other in their results, but they are as much below the corresponding barometric observations which I consider the true heights, as the results by the Madras Tables are above the true heights. Some of them curiously coincide within a foot or two of the heights determined by corresponding barometrical observations, but this coincidence must be the result of mere accident. Taking the mean of all the thermometric observations at a station calculated by the three Tables, and the mean of all the corresponding barometric observations at the same place, the utmost difference is 107 feet, in less than 600; and the least difference is 8 feet, in about 3000; but as the thermometric heights in which the difference of 107 feet occurs were single observations, made by a gentleman who had newly begun to use his thermometers, they may be looked upon as probably less accurate than subsequent trials would have made them. This is scarcely an unjust inference, as it will be seen that the next greatest difference made by the same gentleman was only 24 feet in 4490. It must be admitted, however, that this amount of error is just as likely to occur in heights of 100 feet as in those of 10,000. My thermometers were not graduated to less than half-degrees, and long practice enabled me to determine the height of the mercury in the stem to one-twentieth of a degree; but I would recommend thermometers being used in which the degrees are graduated to fifths or tenths of a degree. On the whole, I think the results of six years' experience justify me in saying, that common thermometers may be satisfactorily used to supply the place of barometers

correct. The late Archdeacon Wollaston, aware of these facts, invented the thermometric barometer, to supply the place of the ordinary barometer. This instrument is very sensible, but it is very fragile, from the great weight of the bulb, compared with the slenderness of the stem; moreover, there are some complex accompaniments, and the instrument is also expensive: in short, I found it not fit for *rough work* out-of-doors, having had three destroyed at the outset of my labours; and the same opinion is expressed by Mr. James Prinsep, of Calcutta, who is well known for the practical application of his scientific knowledge. I had then recourse to common thermometers, and, with certain precautions in their use, found them answer my purpose sufficiently well. A tin shaving-pot was my boiler; dry sticks and pure water were usually to be had, and by the time my barometers were settled, I was ready to take the boiling temperature. The following is a sketch of the apparatus.

Fig. 9.



A. A common tin pot, 9 inches high by 2 in diameter..

B. A sliding tube of tin, moving up and down in the pot; the head of the tube is closed, but has a slit in it, C, to admit of the thermometer passing through a collar of cork which shuts up the slit where the thermometer is placed.

D. Thermometer, with so much of the scale left only as may be desirable.

E. Holes for the escape of steam.

It will be seen that the chief part of the scale usually attached to the thermometer is removed, only so much of it being left as may be desirable: I however permitted the brass scale of one of my thermometers to remain, and I did not discover that it was the cause of error. Previously to taking the thermometers inland, it is necessary to ascertain their boiling points at the level of the sea; for in many instances the scales are so carelessly applied, that a thermometer may indicate a boiling temperature of 213°, 214°, or 215° at the level of the sea; one of mine stood at 214·2 when water boiled. Nevertheless, by making a deduction of 2° 2′ in all observations, the indications rarely differed five-hundredths of a degree from the other thermometer, of which the boiling point was 212°: the temperature of the air and the height of the barometer at the time the *verification* of the thermometers is made, must be noted. The following is the manner in which my observations were taken:—from 4 to 5 inches of *pure* water were put into the tin pot; the thermometer was fitted into the aperture in the lid of the sliding tube by means of a collar of cork; the tin tube was then pushed up or down, to admit of the bulb of the thermometer being about *two inches* above the bottom of the pot. Violent ebullition was continued for 10 minutes or a quarter of an hour, and the height of the mercury was repeatedly ascertained during that time, and the temperature of the air was noticed. Similar operations were repeated with a *second* thermometer, for it is never safe to rely upon *one* instrument. Having obtained the boiling points, it remains to determine the value of the indication of diminished pressure when the observations are taken above the level of the sea. The elastic tension of steam at different points on the thermometric scale has been determined by experiment, but not at regular intervals on the scale, nor with similar results by different persons. Tables, therefore, computed from the formulæ of the various experiments, do not accord; but, in three Tables which I have in my possession, the heights computed by them, when compared with heights determined by corresponding barometrical observations with previously compared barometers

tions differ more than $\frac{1}{500}$ of a foot, the observations are repeated till a fair series is obtained; after which an independent reading is entered by the observer as before.

If the line to be levelled be a long one, it should be divided into intervals, the length of which must vary with the facility with which proper bench-marks can be found. These latter should be very permanently recorded; the best consist of copper bolts let into the corners of stone buildings, towers of churches, etc., and run with lead. Their position should be accurately defined in the field-book.

The following is the form of field-book used:—

Date.	Hour.	Barometer.	Attachd Thermometer.	Hygrometer.	Attached Thermometer.	No. of Observation.	Bearing of the Back Station.	Distance of Back Station.	Bearing of Forward Station.	Distance of Forward Station.	Number of Divisions of Micrometer Scale for 1 foot of Staff.	Back Reading.	Front Reading.	Rise.	Fall.	Total Rise.	Total Fall.	Remarks.

ON THE USE OF COMMON THERMOMETERS TO DETERMINE HEIGHTS.*

Having been recently applied to by two gentlemen about to travel—the one in Africa and the other in Asia Minor—for a description of the thermometers and apparatus used by myself for some years in India for determining heights by the boiling temperature of water, I have ventured to believe that a brief account of a process which I found to produce results sufficiently near to the truth for most practical purposes, may not be unacceptable to some members of the Society, particularly as I carried on my barometrical observations contemporaneously, and thereby obtained data for fixing the value of certain points on the thermometric scale. To determine heights accurately, good barometers are necessary, which have been carefully compared with a standard barometer: the observations must be taken simultaneously at the upper and lower stations; and the temperature of the mercury and the air, and the hygrometric state of the latter, must be noted. Heights so determined, when tested again in the same or succeeding years, I have rarely found to vary more than 10 or 20 feet in 4000 or 5000. When barometers are used which have not been previously compared with a standard, when the observations are not simultaneous, and when the pressure and temperature at the level of the sea are *assumed*, the results may by accident be near to the truth, but they will usually be from 100 to 300 feet wrong,—at least such is the result of my experience within the Tropics. But good barometers are very costly; they are troublesome to carry, are particularly exposed to accident on a journey, and get out of order by the escape of the mercury, which being frequently unobserved, the barometer continues to be used as if it were

* By Colonel W. H. Sykes, F.R.S. Extracted from the eighth volume of the 'London Geographical Journal,' by permission of the Author.

METHOD OF OBSERVING.

The method of observing adopted for ordinary levelling is, to divide the line to be levelled into convenient lengths, seldom placing the staves more than 400 or 500 feet apart. The instrument is placed as nearly as possible equidistant from the staves, by which means the errors of curvature and refraction are got rid of, and even a slight error in the collimation of the instrument cannot materially affect the result. The heights marked upon the staves by the horizontal wire are then read off by the observer himself, and entered in a field-book, and the difference of those heights gives the difference of level between the first two points. The staff at the back station is then sent forwards, the instrument again set up at some point equidistant from the staves, and another observation taken, which fixes the comparative level of another point. These operations are repeated as many times as may be necessary to complete the whole line; the forward station of one observation necessarily becoming the back station of the next.

The observations are generally entered in the form of a Table: this may be drawn up in various ways. The following is given as a simple form :—

No. of Observation.	Distance between the Staves.	Back Station.	Forward Station.	Rise.	Fall.	Total Rise.	Total Fall.	Remarks.
1	400	5·72	11·35	—	5·63	—	5·63	
2	350	4·31	6·54	—	2·23	—	7·86	
3	480	2·17	9·89	7·72	—	—	0·14	
4	300	3·35	8·60	5·25	—	5·11	—	

In the first column is entered the number of the observation; in the second, the distances between the staves. The third and fourth show the readings of the instrument; and the differences of those readings are entered in the fifth or sixth column, according as the result shows a rise or fall between the two points. In the seventh and eighth columns are carried out the total rise or fall of each point from the first station; and the ninth column, headed "*Remarks*," contains references to bench-marks, cross sections, or any other information that may be subsequently required.

Where great accuracy is required, a level of larger dimensions than ordinary is employed: a small riding level is adjusted to the horizontal wire, and, besides ensuring the correct position of the latter, is very useful in setting up the instrument approximately level. The micrometer scale is divided to 200ths of an inch. The staves made use of are those with metal vanes and mirrors before described, and canvas screens are provided to protect them from the wind.

In observing, the instrument should always be placed by measurement equidistant from the two staves. The distance of each should rarely exceed 200 or 300 feet, and in marshy or soft ground it should be diminished to 150 feet. When the instrument has been adjusted, and the bisection of the sight vane made, the assistant at the staff reads off the vernier and inserts the reading in a rough field-book. The vane is then shifted, and the instrument thrown out of true level. The latter is again adjusted, a second observation made, and the assistant records it as before. If the two readings do not differ more than $\frac{1}{300}$ of a foot, he makes a signal to the observer, who proceeds to the staff, and enters a third independent reading of the vernier in his own rough field-book. This is compared with those of the assistant, and an entry made in the fair field-book of the mean of the three. If, however, the two first observa-

with vanes facing in opposite directions, and, whenever it is possible to avoid it, the vane recording one observation is never disturbed till the next is obtained. The vanes are generally of metal: they move on the staff by means of a sliding clasp. This again is connected by an adjusting screw with a spring clasp, somewhat lower down; and the latter can be firmly attached to the staff, when necessary, by means of pushing screws. The adjusting screw is finely cut, so as to admit of a delicate adjustment. When the vane is so high on the staff that the arm cannot reach to manipulate it, a rod is made use of, having a universal joint fitting the head of the screw. A triangular space is cut out from each side of the vane, and the axes are made to coincide with the zero of the vernier which divides the staff. Small mirrors are fitted to the back of these openings, moving upon hinges, so as to reflect the light towards the telescope at different angles of incidence. In observing, the horizontal wire will be seen very sharp and distinct upon the faces of these mirrors: it is made to bisect the triangles, and thereby to coincide with the zero of the vernier; the latter is divided to ·001 of a foot, and the reading can be carried to a fourth place of decimals by the eye. (See figs. 6, 7, and 8.)

Fig. 6.—Back View.

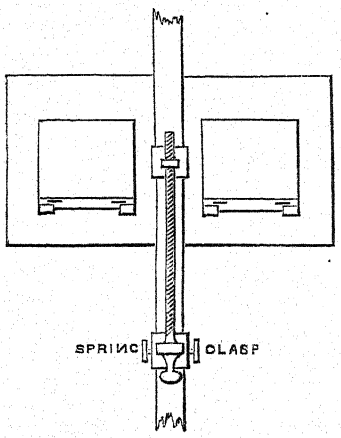
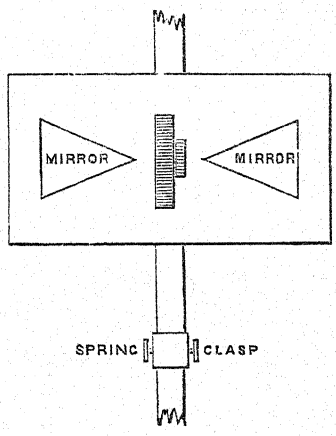
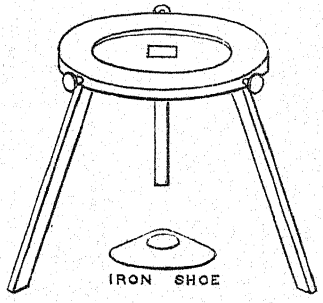


Fig. 7.—Front View.



The staves are supported by tripod stands having on the top a strong brass plate, to which a horizontal motion can be given by means of adjusting screws. The staff is passed through an opening in this, and rests below upon a massive iron shoe, in which an orifice has been made to receive it. The vertical position is then ensured by means of the adjusting screws.

Fig. 8.—Tripod Stand.



A strong wind generally causes so much vibration and unsteadiness in the staves, that it is difficult to obtain a satisfactory result. In this case a strong canvas screen, placed to windward, will be found to diminish the vibration very materially.

1st. To make the level perpendicular to the vertical axis.

2nd. To make the line of collimation parallel to the level.

The first is effected in the same way as in the Y level, substituting for the milled screw under the Y the capstan screws which attach the telescope to the horizontal bar.

The second adjustment is effected by noting the height of the intersection of the cross wires on a staff two or three hundred yards distant, and then making the instrument and staff change places. If the difference of level remain the same, the adjustment is correct; if not, the vane on the staff is to be moved one-half the observed difference, and the intersection made to coincide with it by the diaphragm screws near the eye-piece.

A sheet of water furnishes an easy mode of adjusting the line of collimation. A mark being fixed at some convenient distance, at exactly the same height from the water as the instrument to be adjusted, the cross wires have only to be made to intersect each other at that point.

The telescopes of spirit levels are generally provided with one horizontal and two vertical wires. Some have also a finely-divided micrometer scale, which is a very useful addition, inasmuch as it enables the observer to read off any small portion of the staff that may be intercepted between the horizontal wire and the nearest upper or lower division. It may also be used where minute accuracy is not required, to fix approximately the staves at equal distances from the instrument, or even to estimate the actual distance of any point.

In order to read the staff by the micrometer scale, it is necessary to note the run of the latter for each observation, as it will necessarily vary with the distance.

In order to fix the staves approximately at equal distances from the instrument, it suffices to note the value upon the scale of any given unit at the back station, and then cause the second staff to recede till a similar unit subtend the same number of divisions.

If we wish to estimate the actual distance of any point, it is necessary to have a Table prepared from previous observation, showing the number of divisions of the scale a given height on the staff (say 5 or 10 feet) subtends at 100, 150, 200, and so on to 1000 feet. Intervening distances may be found by taking the nearest number of divisions in the Table, and the distance corresponding to it: these will form the two first terms of an *inverse proportion;* the third being the observed number, and the fourth the distance required,

The levelling staves made use of for ordinary levelling are unprovided with vanes; the divisions, 10ths and 100ths of a foot, being so distinctly marked that the observer is enabled to read them off himself. The figures are generally inverted, to suit the inverting telescopes now in use. The staff rests upon an iron slide, within which it can be turned upon a pivot without being lifted from the ground.

Where minute accuracy is required, the staff is never turned; it is provided

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angles to the principal level, which affords very great facility in setting up the instrument and adjusting for observation; it likewise has a reflecting mirror, mounted with a hinge joint, and capable of being placed on the principal level tube, and adjusted, to show the observer if the instrument shifts from its horizontality whilst he is noting the observation: it also possesses other important though minor additions, all of which, in fact, could be applied by the maker to the other kind of instruments, if ordered.

"From the large aperture and short focal length of the telescope, the instrument has altogether a dumpy appearance, and hence it is generally known by the cognomen of 'Gravatt's Dumpy Level,' usually of nine or fourteen inches. We have seen some beautiful specimens of this kind of levelling instrument constructed for I. K. Brunel, Esq."—*Simms on the Practice of Levelling.*

thin white glass. The water must be slightly coloured (cold tea answers very well).

The spirit levels in general use are the ordinary Y level, so called from the nature of its supports, and Troughton's improved level. These instruments are so well known that it is unnecessary to describe them; but the following directions for their adjustment may be found useful.

In the Y level there are three points to be attended to:—

1st. To see that the intersection of the cross wires is exactly in the centre of the telescope. This is called the adjustment for the line of collimation.

2nd. To see that the level is exactly parallel to the axis of the telescope.

3rd. To see that the axis of the telescope, or line of collimation, is perpendicular to the vertical axis upon which it turns.

The first of these is tested by making the intersection coincide with some well-defined distant point, and then turning the telescope round in the Y's. If the adjustment be correct, the coincidence will remain perfect during the whole revolution; but if in error, the intersection will be seen to describe a small circle on the distant object. In the latter case the wires must be moved by means of the small screws of the diaphragm till their intersection occupies the centre of the observed circle. If this be correctly estimated, the telescope may be turned round again without any eccentricity being observed: generally speaking, however, this adjustment will require repeated trials.

The second adjustment is tested by bringing the telescope over two of the plate screws, and moving the latter till the bubble is in the centre. The telescope is then to be reversed in the Y's, and if the bubble still occupy the centre, the adjustment is correct. Should it however incline to one side, it must be brought halfway back by the capstan-headed screw under the end of the level, and the remaining half by the plate screws. If this be correctly done, the bubble will remain in the centre in both positions. Owing however to the difficulty of estimating the half-error, this adjustment will generally be found to require many trials.

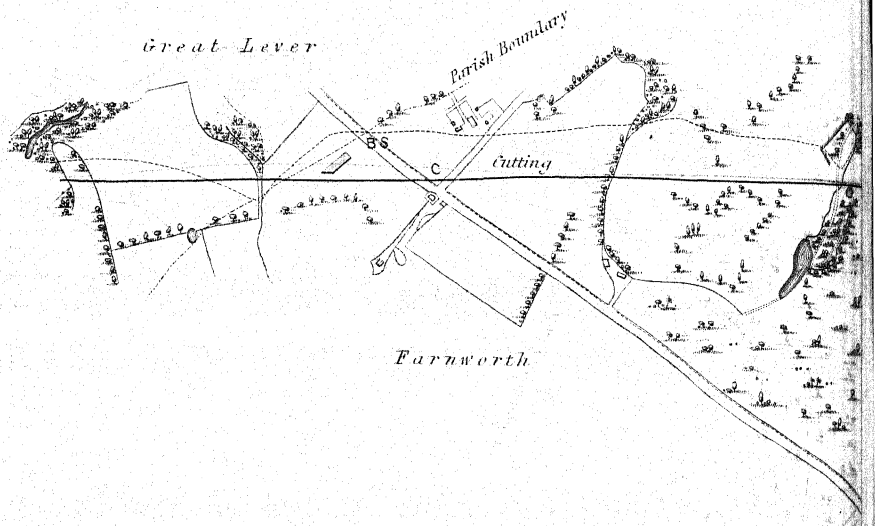
The third adjustment is also tested by bringing the telescope over two of the plate screws, and the bubble to the centre; but, instead of reversing the telescope in the Y's, the instrument is turned round a half-circle on the vertical axis, when the telescope will be again over the same screws the reverse way. If the bubble has moved from the centre, it must be brought halfway back by means of the milled screw under the Y near the eye-piece, and the remaining half by the plate screws. The same operation being repeated with the other pair of plate screws, the adjustment will be complete.

N.B.—No instrument should ever be used till it is ascertained that these adjustments are correct.

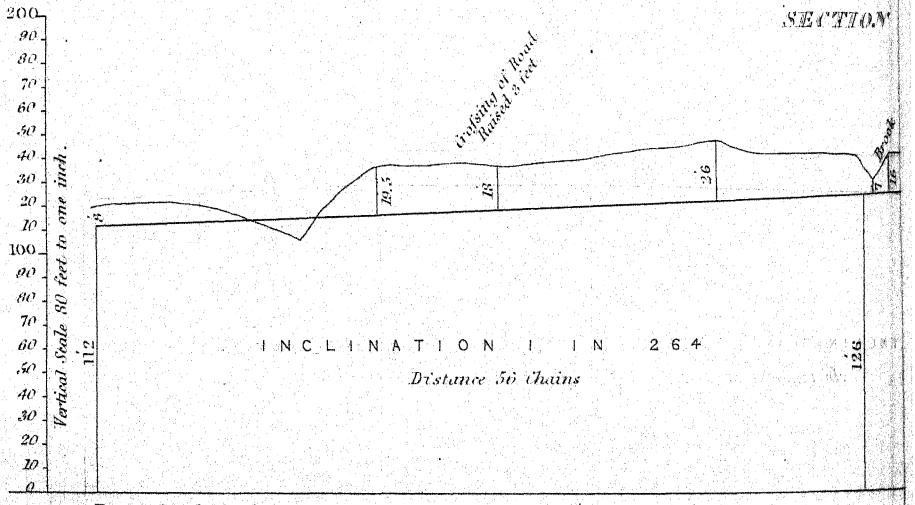
In Troughton's* improved level, the spirit level itself is firmly bedded in the telescope; there are therefore only two adjustments:—

* "*The Dumpy Level.*—This modification of the spirit level has but recently been introduced by William Gravatt, Esq., and bids fair to become the favourite instrument among Civil Engineers. In its general figure it does not differ very essentially from Troughton's improved level, but it possesses many decided advantages. The aperture of the object glass is much larger for the same length of telescope; consequently more rays of light are admitted to the eye, producing the advantages of greater distinctness. We lately tried a *fourteen-inch* level constructed upon Mr. Gravatt's principle, and found that we could distinctly read the levelling staff at twenty chains (a quarter of a mile) distant, which was the utmost we could do with a *twenty-inch* level upon the old construction: we have therefore the advantage of a more portable instrument, fourteen inches in length, capable of performing the same work as a more cumbersome one of twenty inches. Besides this advantage, the instrument in question is more complete in its details. It possesses a cross level, placed at right

PARLIAMENTARY



SECTION



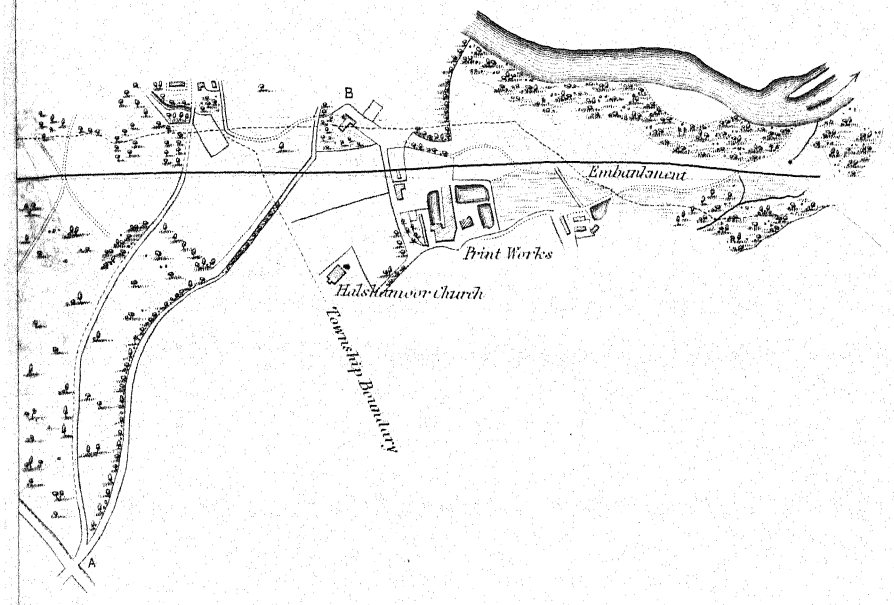
Datum Level Top level of an 18 feet tide by guage at St. Georges Dock.

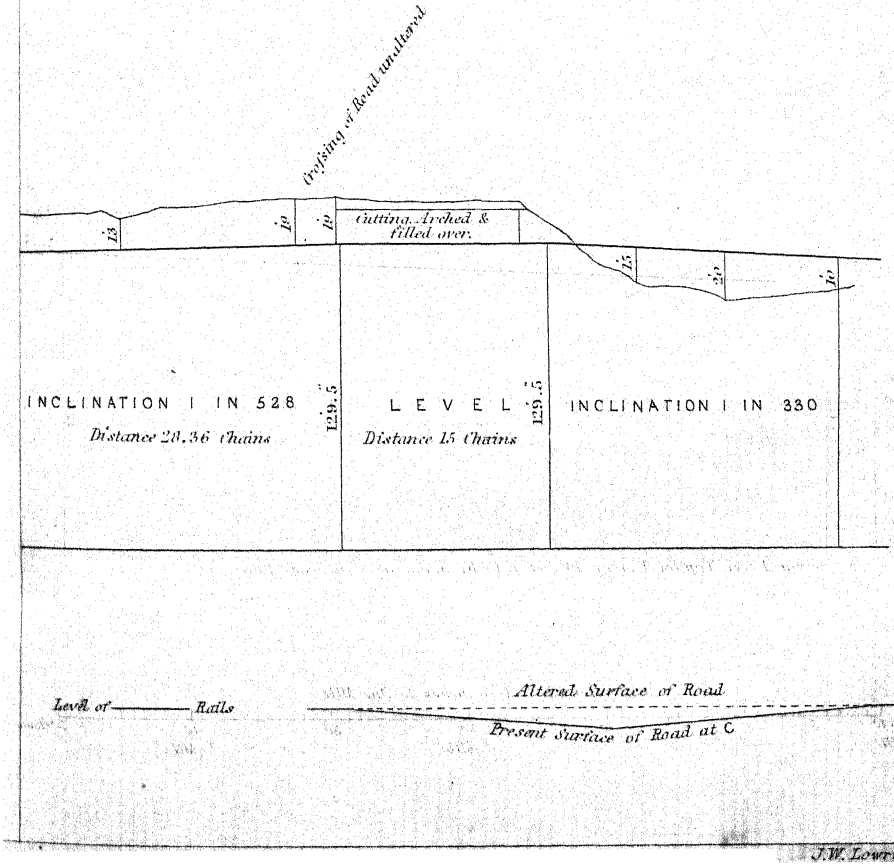
Horizontal Scale 6 inches to One Mile

Chains 10 5 0 10 20 30 40 50 Chains
1/8 Mile 1/4 Mile 1/2 Mile

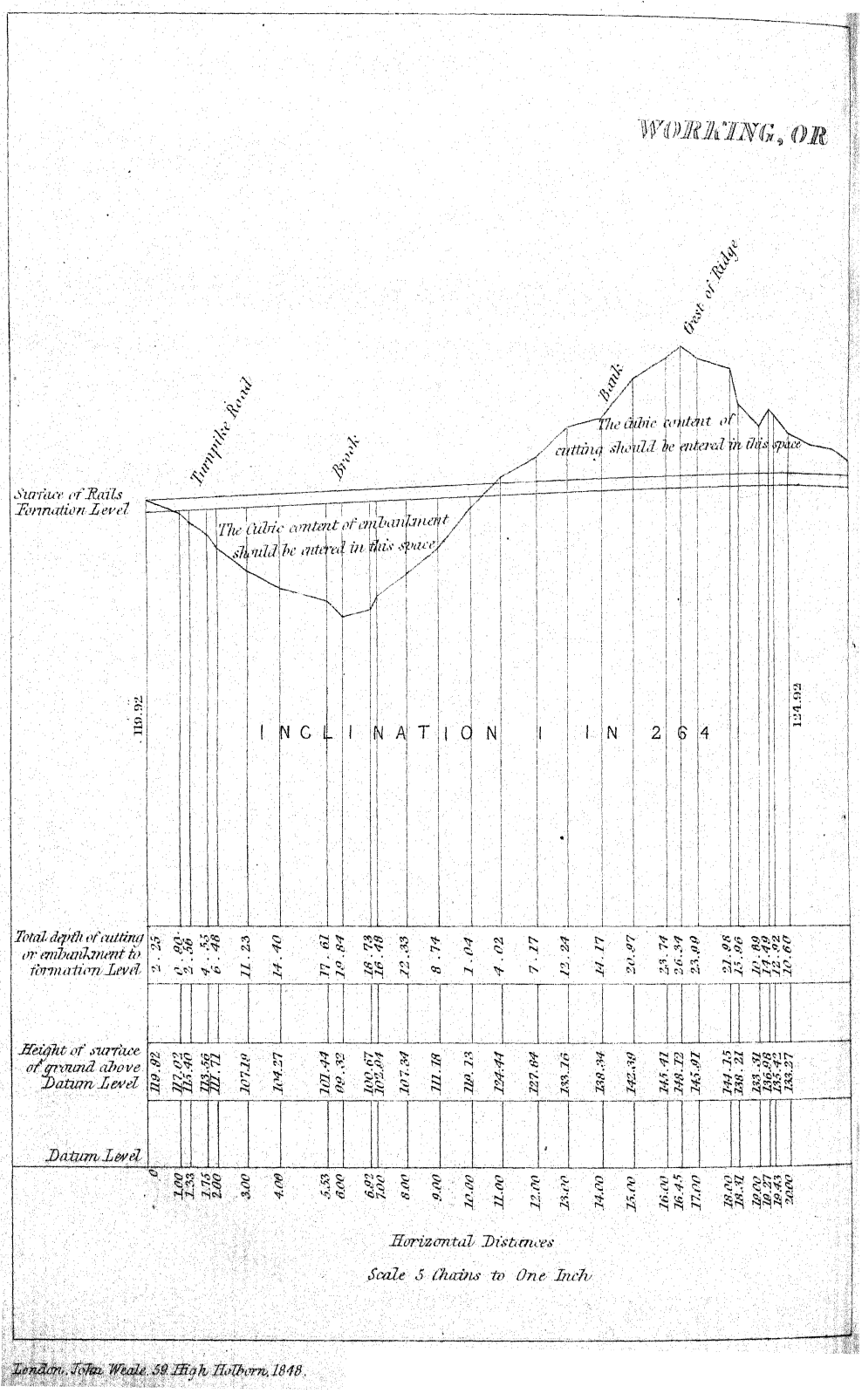
London, John Weale, High Holborn 1848.

PLAN.



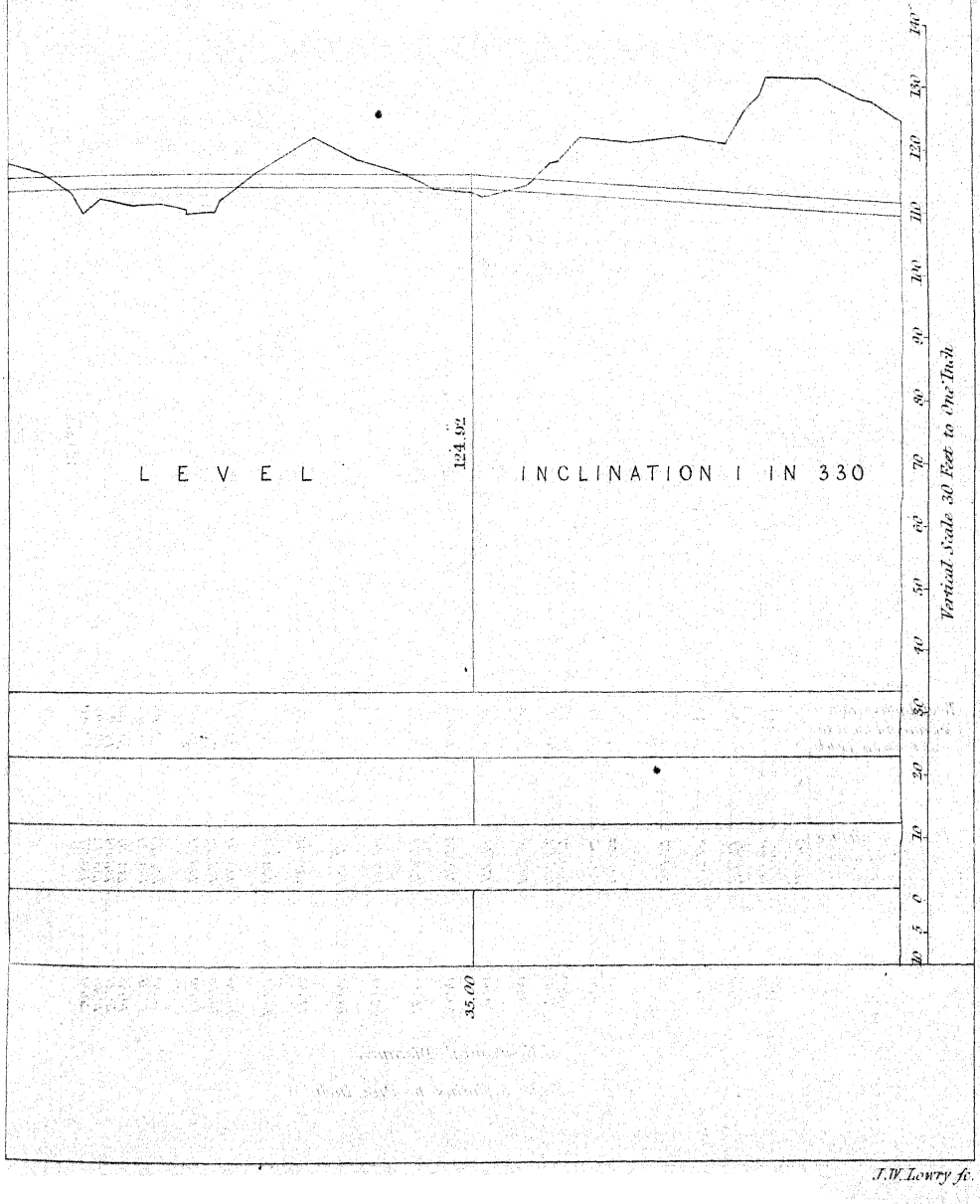


J.W. Lowry fc.

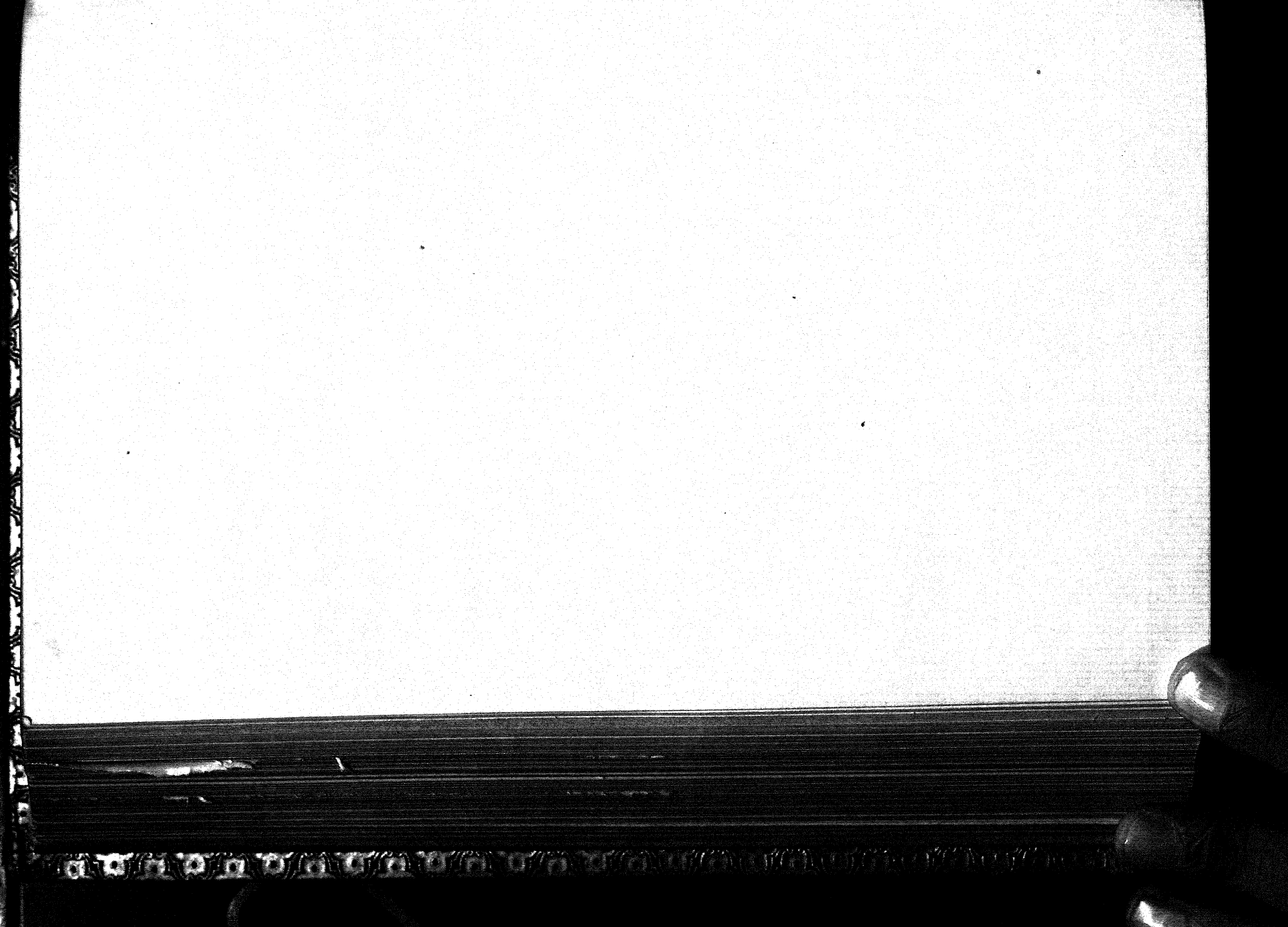


London, John Weale, 59 High Holborn, 1848.

CONTRACT SECTION.



J.W. Lowry fc.



Form of Field-Book for Working Sections.

Distance in Chains.	Rise.	Sights.		Fall.	Reduced Levels.	Transverse Levels.		Remarks.
		Back.	Forward.			Left.	Right.	
					115·73			Level of bench-mark on B.S. above datum level.
	4·09	7·31	3·22		119·82			
0		3·41	6·31	2·90	116·92			
1		6·31	7·90	1·59	115·33			
1·33		8·70	10·57	1·87	113·46			On edge of road.
1·75		10·57	12·42	1·85	111·61			Do. do.
2		0·71	5·23	4·52	107·09			
3		5·23	8·15	2·92	104·17	7·32	10·11	
4		8·15	10·98	2·83	101·34			
5·53		11·98	14·10	2·12	99·22			Top of bank.
6	1·35	9·17	7·82		100·57			
6·92	2·27	7·82	5·55		102·84			Bank of brook.
7	4·40	5·55	1·15		107·24			Bottom of do.
8	3·94	8·15	4·21		111·18			
9	7·85	11·32	3·47		119·03	1·75	4·84	
10	5·41	10·19	4·78		124·44			
11	3·40	9·37	5·97		127·84			At foot of elm-tree in hedge.
12	5·32	8·54	3·22		133·16			
13	5·18	9·29	4·11		138·34			
14	4·05	10·51	6·46		142·39	7·22	5·55	Top of bank 3 feet high.
15	3·02	6·61	3·59		145·41			
16	2·61	3·59	0·98		148·02			
16·45		2·56	4·77	2·21	145·81			Crest of ridge.
17		4·77	6·53	1·76	144·05			
18		6·53	12·47	5·94	138·11			
18·31		1·86	6·77	4·91	133·20			
19	3·67	6·77	3·10		136·87			Bottom of ditch.
19·27		3·10	4·66	1·56	135·31			
19·43		4·66	6·83	2·17	133·14			B. M. on mile-stone, 215 links to east-ward.
20								
	56·56	192·73	175·32	39·15				
	39·15	175·32						
	17·41	17·41						

Form of Note-Book for Setting out Side Widths.

No. of Picket.	Depth of Cutting, or Half of Embank-ment.	Computed Half Width.	Transverse Level Readings.			Difference of Level. + −		Difference of Level × ratio of Slope.		Corrected Half Width.	
			Left.	Centre.	Right.	Left.	Right.	Left.	Right.	Left.	Right.

LIME, ITS PROPERTIES, USES, AND MANUFACTURE.*—It is not intended to enter into a chemical investigation of the nature and properties of lime; but as a knowledge of the leading principles is so necessary to a perfect understanding of the subject, we detail such facts as we deem most useful, endeavouring at the same time to render them as plain and intelligible as possible.

Lime is prepared for the purposes of building, by calcining or burning with a red heat, in a kiln properly formed, such substances as chalk and most of the varieties of limestone and marble.

The whole of these substances in the natural state, whether chalk, stone, or marble, are called *limestone*. The fixed air which this contains is termed *carbonic acid*, and the lime that is used in building must be deprived of its fixed air by being burned. Thus the perfection of lime prepared for building purposes consists principally in being deprived of its carbonic acid, most of which is carried off, during the process of calcination, in the form of gas or steam.

It was the opinion of the ancients, and is still partially received among our modern builders, that the hardest limestone furnishes the best lime for mortar; but experiments have proved it to be a mistake, and that the softest chalk-lime, if thoroughly burned, is equally durable with the hardest stone-, or even marble-lime. But although stone and chalk-lime are equally good under this condition, there is a very important practical difference between them, which is this: the chalk-lime absorbs carbonic acid with much greater avidity, which reduces it to powder, and if it be only partially burned, it will, on the application of water, fall into a coarse powder also, which stone-lime will not do.

Limestone loses nearly half its weight by burning; and if properly burned, it is more than doubled in quantity or bulk when *slacked*, that is, when reduced to powder by pouring water upon it.

For making mortar, the lime should be used as soon as possible after being taken from the kiln; for if left long after exposed to the air, it will separate, first into small lumps, then into a fine powder, and in this state will make but a very inferior mortar, because it has already again absorbed as much carbonic acid as it can possibly contain, and consequently, when made up into mortar, it has not the power to absorb any more.

There is a difference of opinion among practical men as to the proportions of lime and sand to be used in making mortar; that of three measures of sand to one of lime being most approved, provided the ingredients be good and well beaten. Qualities, however, will differ in degree; therefore the best guide will be, to use no more lime than will be sufficient to surround the particles of sand, and give the mass the necessary degree of plasticity, or, as workmen would say, make it hang together.

Mortar in which sand predominates, requires less water in preparing, and therefore *sets* sooner: it is harder, and less liable to crack in drying, for this reason, that lime mixed with water shrinks in drying, while sand retains its original magnitude.

The best mortar for dry building is thus prepared:—Take well-burned lime fresh from the kiln, in which state it is called *quick-lime*, strew any quantity at a time, say a bushel, on a stone floor, and pour water equally over the whole till it is saturated, or will absorb no more; turn it up in a heap with a shovel, when it will crack and

* Compiled by Major-General Lewis.

snap, and steam will begin to issue from it; cover the heap over with clean sharp sand, say three bushels, taken from the bed of a running stream, or washed in clear water through a sieve, which will confine the steam and heat; proceed in like manner with the remainder, and then let it rest for a time. In this state it generates a powerful heat, which it keeps up long enough to cook a joint of meat by. This method of cooking is sometimes resorted to by workmen when the heap is large, in which case they enclose the meat in a tin box or a cloth, to keep it clean; and although the heat is not of an inflammable nature, it may be made to communicate fire to wood or other light substances, through the agency of iron: thus a quantity of quick-lime being slacked and turned up against a boarded fence or building, will set fire to the same through the agency of the nails, which will be rendered red-hot, or nearly so, by the heat of the lime. During this time, the decomposition of the lime is going on: when it is completed, the heat begins to subside, and the lime is reduced to an impalpable powder, and is in this state called *slacked-lime*. It is then turned over with a shovel so as to mix the lime and sand well together, and sifted or screened: the parts left behind, being pieces of limestone which have passed through the kiln unburnt, or partially so, are called *lime-core*, and should be thrown aside. If a superior mortar is required, it is afterwards beaten with a wooden beater upon the stone floor. When it is required for plastering, a quantity of hair from the hides of bullocks is stirred in and mixed with the mortar, by means of a double-pronged hook, like a hay-fork, with the tines or prongs turned downwards.

The hardness which good mortar attains soon after being used, is said to be the effect of crystallization.

Shells are sometimes calcined, and afford a lime which will make a very good mortar. Mortar made of this lime *sets*, or becomes hard, quicker than that made of common limestone.

Lime-kilns are built of different forms or shapes, according to the manner in which they are to be wrought, and the kinds of fuel to be employed.

The rudest and most ancient kind of lime-kiln is probably that made by excavating the earth in the form of a cone, of the size required, and afterwards building up the sides, or not, according to the circumstances of the case. The materials being then laid in alternate layers of fuel and limestone, properly broken, till the whole is filled up, the top is covered with sods (thence termed a *sod-kiln*) in order that the heat may be prevented from escaping, and the fire lighted at the bottom. The whole of the contents are burnt in a greater or less space of time, in proportion to the nature of the limestone and fuel, and the quantity that is contained in the kiln. When the contents are cold, the lime is drawn or taken out from the bottom, and the kiln is filled again, if necessary. Burning in this way, although it may be found most convenient in some situations, where lime is only occasionally wanted, and in small quantities, is not to be recommended when other means can be adopted, as it is both tedious and uneconomical.

Where lime is much wanted, they therefore use *perpetual* or *draw-kilns* built of stone or brick; the latter is preferable, as being better adapted for standing an excessive degree of heat.

Burning with peat is sometimes practised, and, considering the rude and ill-constructed kilns which are used for the purpose, it is astonishing with what success the operation is performed. It is stated that limestone is sufficiently calcined by placing it, with alternate layers of peat, in kilns formed of turf; but owing to the quantity of ashes which fall from the peat, the quality of the lime is considerably deteriorated, and, from the open and exposed situation of most of them, the waste of fuel is immense.

An economical method is practised with effect in many parts of the country which are situated at a great distance from coal, in kilns somewhat similar to the brick-kiln and, from furze and similar fuel being used in them, called *flame-kilns*. The walls are built of brick, and should not be less than from 4 to 5 feet thick when not supported by a mound or bank of earth, and built battering or diminishing upwards: the dimensions inside, 13 feet by 12 feet, and 12 feet high, or thereabouts. In the front wall there are three arches, each about 1 foot 10 inches wide and 3 feet 9 inches high. When the kiln is to be filled, three arches are formed of the largest pieces of limestone, with one end adjoining and open to the arches in the front wall, and running the whole length of the kiln to the opposite side. When these arches are formed, the limestone is thrown promiscuously into the kiln above the arches, to the height of 7 or 8 feet, over which are frequently laid 15,000 or 20,000 bricks, which are burned at the same time with the limestone. When the filling of the kiln is completed, the three arches in the front wall are filled up with bricks almost to the top, room being left in each sufficient only for putting in the furze, or other fuel, which is done in small quantities, the object being to keep up a constant and regular flame. In the space of about forty hours, the whole of the limestone, about 120 or 130 quarters, together with 15,000 or 20,000 bricks, are thoroughly burned.

Fig. 1.

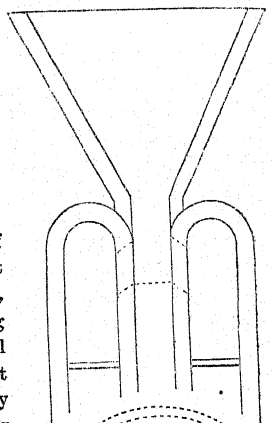
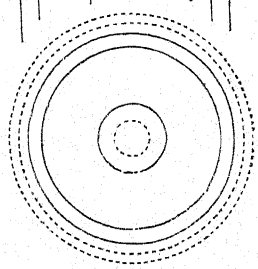


Fig. 2.



We need not repeat the caution respecting the thoroughly drying the walls of such kilns by a continued and gentle heat, before the full heat is employed in them.

The form of lime-kiln found most advantageous is that of an inverted cone.

We here give a section (fig. 1) and plan (fig. 2) of a lime-kiln of this description, which is built of brick, and in the following manner: The spot fixed upon should be near to the limestone pit; a circular hole must be dug in the earth about 12 feet diameter at top, and rather narrower at the bottom, and when the top of the kiln is to be even with the surface of the ground, about 14 feet in depth. The foundation is laid and carried up as a circular solid base, to the height of 3 feet, when it is built hollow, and two or more *eyes* or draught-holes are left, 1 foot 6 inches high by 9 inches wide. At the distance of 2 feet 6 inches from this base, another wall is built, forming a passage round it, which is called the chamber, and has a small doorway in front, or at that side from which the lime can most conveniently be taken out. When the walls and base are carried up to a sufficient height from the floor of the chamber, an arch is turned over it, and the conical part of the kiln commences, which is 18 inches at the bottom, and expands as it goes up till it has spread out to the diameter of 8 feet at the top. The bricks selected for the purpose should be such as will best stand the fire, and laid with a thin joint of very good mortar. Movable gratings are fixed in the draught-holes, to keep the lime in till drawn. Iron plates, or blowers, as they are called, are also fitted to them, to regulate the draught. The outward door is generally an open one, to allow a free passage to the air, very little lime

being kept in the chamber, as it is not drawn till the cart arrives to take it away. When the situation of the kiln will not allow of the ground being sloped down to the door of the kiln, steps are formed part of the way up, and a wing-wall is built on each side, to keep up the ground. As soon as the mortar is set, the ground should be filled in, and well rammed up to the sides of the kiln as the work proceeds.

In describing the way in which the process of burning is carried on, we would be understood as speaking more particularly of the lime made from chalk, although our remarks will in most cases apply to stone-lime also.

The chalk for making lime is dug from a bank or cliff, or in a pit sunk through the upper strata in the earth, whence it is drawn up in buckets by means of an axle and wheel; the latter method being in general attended with most trouble. The large lumps are brought in barrows or baskets, and laid in heaps round the kiln. The *lime-burner*, having in his right hand an instrument like a small pick-axe, beginning at the end of one of the heaps, chops the lumps into the requisite size, (about the size of a man's fist,) and sitting across that which is already chopped, he continues chopping, drawing it towards him, and advancing till he gets to the end of it. If there be much small chalk, as is sometimes the case, it is separated by sifting, and thrown aside. Supposing the fire to have been extinguished, he proceeds to light it by laying a quantity of wood and large coal at the bottom of the kiln; over this is laid a layer of limestone, and then another of small coal; fire is then put to the fuel, and another layer of chalk added: when the fuel in the lower part of the kiln is nearly consumed, a hollow space is formed below, and the surface is united or caked together, till the *lime-burner* breaks it up with a large poker made of wood, and pointed with iron, like a pike, and long enough to enable him to reach the bottom of the kiln with, when standing upon the top.

As to the lime hanging to the sides of the kiln, it will be supposed that the surface of the kiln, after being exposed for some time to a continual red heat, will not be very smooth; on the contrary, it is thereby rendered very uneven, and the coal lying in contact with it in the course of its decomposition by the fire, unites itself and hangs to this rough surface as it would to any other of a similar material, without reference to its form or shape. It is to prevent the ill effects which might ensue from this circumstance, as well as to give full effect to the fire, that the lime-burner is provided with his long poker; and if he make proper use of it by breaking up the surface of the mass, and disengaging it round the sides occasionally, as well as before drawing off the lime, the object will be fully answered.

When the lime is thoroughly burned, it drops down into the bottom of the kiln; and when a sufficient quantity is there collected, the grating is removed from one or other of the draught-holes, through which the lime rolls and falls upon the floor of the chamber, and the grating is returned to its place. Every time after breaking up the surface of the limestone in the kiln, a thin layer of small coal is strewed over the surface, then another layer of limestone, and so on; the number of layers and quantity in each being regulated by the quantity of lime in demand in a kiln of the above dimensions: this may vary from 10 to 140 bushels per day, but if it be ever so trifling, it is advisable to keep the fire always in, if possible, as when it is once let out, it is not properly got up again without a great loss of time and fuel.

A kiln of this description produced lime of a very good quality, and fit for any of the ordinary purposes of building, on an average of 400 bushels per week, and at the rate of three and a half bushels of lime to one of small coal: the fire was never let out but once a year,—that in the midst of winter, for about a week, and not even then when there was the least demand for lime, which happened to be the case in two or three instances.

In burning, it is necessary to keep the fire up at a regular red heat, and not to make it too powerful, or it will cause the lime to vitrify, and the surface of the lumps being thereby covered with a glazed coating, will be rendered useless.

The coal* used is small, almost dust, and passed through a screen to give it uniformity, a shed should be provided for it, to keep it dry, and as near the kiln as may be found convenient. If a shed, or some such shelter, were erected for the limestone also, it would be found advantageous: for when taken from the pit, even in the dryest weather, it contains some moisture, but in rainy seasons, in consequence of lying round the kiln in small heaps, it is often completely saturated with wet before it is put in the kiln, which causes an otherwise unnecessary quantity of fuel to be expended upon it. Breeze, such as is used for burning clamp-bricks, is also, by some, used in burning lime, either alone, or mixed with small coal.

CAPTAIN SCOTT'S CEMENT.

A new principle in the formation of cement has lately been applied by Captain Scott, R.E., viz. that of producing one of hydraulic properties by "subjecting lime in a heated state to the action of sulphurous acid." In describing it he says:—

"In carrying out this process the following method is at present practised; quicklime, prepared in any of the ordinary methods, is placed on a perforated arched floor in a layer 3 feet deep, having beneath it a fire-place 1 foot broad, with cheeks sloping outwards to the full width of the kiln, and extending throughout its whole length. The fire-bars are 1 foot 3 inches from the ground, and the perforated fire-brick arch consists of two 4½-inch rings, 3 feet 6 inches above them. The whole is covered in with a 9-inch semicircular arch, springing 2 feet 6 inches above the perforated floor.

"At the end of the kiln furthest from the fire-door, is a hatch or opening 2 feet 6 inches wide and 4 feet high, for charging and drawing. This is closed during the process with a double wall of bricks, having an intermediate space of a few inches filled with lime dust. The chimney is over the hatch, and is raised about 1 foot above the outer ring of the semicircular arch which forms the roof. The kiln is 6 feet long and 2 feet 6 inches broad, and therefore in a depth of 3 feet contains 3 cubic yards of lime. The kilns which the manufacturers propose to erect (that above described being intended for experimental purposes only) will be about 23 feet long and 10 feet wide, with four fire-places, two at either end, separated by a wall of brick extending to the height of the perforated floor. In other respects they will differ little from the small kiln here described.

"When the charge of lime has been raised to a dull glow, the firing is raked out and 30 lbs. of sulphur are introduced into the ash-pit in iron pots. As soon as this sulphur is fully ignited, the chimney is shut up and the ash-pit and fire-door closed, some little air still finding its way in and continuing its combustion. At the end of 7 or 8 hours (in a 3-bushel kiln I find 2 hours sufficient) the charge is raked out, ground to powder, and packed in casks for use. This process is applicable to any lime. The nature of the lime, as respects its mode of combining with water, is now completely altered, for instead of slaking, it will, when mixed with it, gradually harden into a stone-like substance."

This cement, according to Messrs. Lee and Co., the manufacturers, possesses, for internal purposes, all the valuable properties of the Parian cement except whiteness, and can be employed more cheaply than ordinary lime and hair plaster; and for hydraulic purposes is superior to the much esteemed Lias Lime.

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* Brush-wood, furze, timber, and turf or sod, answer sufficiently well for the purposes of hutting. —*Editors.*

Instructions for Use.

"The cement must be kept dry and protected from the air. Use 3, 4, or 5 parts of sand to one of cement, for rendering, and 3 of sand, or less, to one of cement for finishing, according to the work required. The sand to be clean and sharp, and for the rendering coat coarse.

"The surface to which it is to be applied must be well wetted, particularly if the brickwork be old. If this precaution be not attended to, the cement is robbed of the water which is necessary to its becoming a solid mass, and crumbles from the wall. The effect will occur within one or two days.

"In summer time, if exposed to the sun, the cement should be occasionally wetted for a day or two, to prevent a too rapid desiccation, which detracts from the hardness it is otherwise capable of assuming.

"If used for moulding (when 1 or 2 parts of sand to 1 of cement may be employed), the cast must be well wetted, or, still better, immersed in water for an hour or two, before it has become thoroughly dry. For mortar, use 3 or 4 parts of sand to 1 of cement. For concrete, treat it like ground Lias Lime."

LOOPHOLE.*—The term "loophole" is understood to denote the opening in a masonry wall or stockade, for the use of musketry, as an embrasure is for that of artillery.

The nearly uniform dimensions of all infantry muskets of the present day, and a due attention to economy and convenience in building, have reduced the form of the loophole to two or three conditions, adapted to suit the purposes of defence.

It is usual to distinguish these by the direction of the exterior opening. Thus we call the loophole vertical or horizontal, according as the exterior opening is upright or the contrary.

The vertical construction is best adapted for sites where great vertical range is required, such as for the flanking of high scarps, or steep slopes, etc.

Under all other circumstances, the horizontal loophole will be found most effective and most convenient.† It affords greater advantages for defence, because, with great lateral extent, it combines sufficient vertical range to include the height of a man, which, under ordinary circumstances, is all that will be required.

The interior opening of the loophole can be of the same form in both these conditions: for a man to use his musket conveniently, it should not be less than 2 feet wide and 1 foot 6 inches high. Vertical loops are seldom constructed for more than one man to serve at a time; and in brick walls they are placed with their centres not less than 3 feet apart. Horizontal loops, on the contrary, can be constructed to contain two or even three men, the interior opening having an increase of not less than 2 feet per man.

The extent of the exterior opening depends upon the range required, but its width should not exceed 3 inches, and the hole at the exterior should be at least 7 or 8 feet above the level of the ground at the outside, to prevent the loop being marked or fired into.

The length of barrel of a musket in our Service is about 3 feet 3 inches. As it is necessary that the muzzle should extend 3 inches outside of the loop, to pre-

* By the late Colonel Tylden, Royal Engineers.

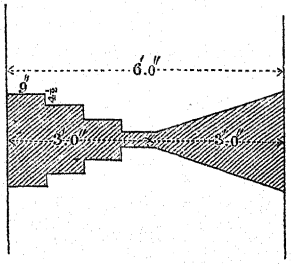
† We do not concur; we conceive that the vertical loophole facilitates the command of the ground in front, and enables the soldier to deliver his fire with greater ease. In galleries for reverse fire and caponnières to flank the ditches, the horizontal loophole may be preferable.—*Editors.*

vent inconvenience from the explosion, it is evident that the ordinary form of loop is inapplicable to a wall of a greater thickness than 2 feet 6 inches, or at most 3 feet.

When this dimension is increased, it becomes necessary to make a corresponding modification in the arrangement of the loop.

Let us take 3 feet as a convenient thickness of wall, and construct the loop either vertical or horizontal, as before described.

Fig. 1.

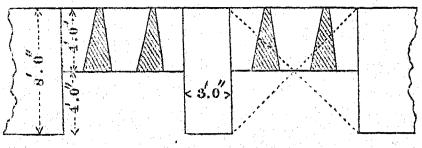


Then, for any additional exterior thickness of wall up to 5 or 6 feet, the sides of the loop can be formed in successive courses of bricks, as described in the late Lieutenant-Colonel Alderson's Memorandum in the eighth volume of the 'Professional Papers,' which is given at length in this Article.

But when the thickness of wall exceeds 6 feet, this method will be found inconvenient, on account of the great increase to the exterior opening; and in this case it is usual to form an arched recess in the interior, of whatever additional depth is required to make up the thickness of wall.

The recess may be made to contain three or four loops, as may be convenient, and if the piers and arch be carried through to the exterior, the formation of the recess does not so much tend to weaken the wall.

Fig. 2.



The following excellent method of forming horizontal loops in brick-work has been suggested by Lieutenant-Colonel Alderson, R.E.

"Horizontal loopholes present a much wider range of fire than vertical ones, for the space exposed; and in boundary walls, defensible barracks and guard-houses, reverse fires, and caponnières, are decidedly preferable.

"The present horizontal loophole is a cast iron frame, built into the wall so as to weaken it as little as possible. It is adapted for a wall three bricks thick.

"The same principle may be adopted in walls of any thickness.

Plate I. figs. 1, 2, and 3.

"Fish-belly girders (*a*, *a*, *a*) are provided to strengthen the upper part of the loophole, and enable it to carry the wall above. Arches, however, may be turned as over window openings, if preferred. Half-inch iron will be sufficient for the sides and bottom of the frame.

"By giving the loop-hole the present form, it sets with great firmness in the wall.

"In reverse fires and caponnières, whose object is the defence of the passage of the ditch, when the enemy is otherwise occupied than in returning the fire of them, external objects will be better seen by making the larger opening of the loophole outside, in which case the smaller opening may be increased from $4\frac{1}{2}$ to 6 inches.

"In boundary walls, barracks, and guard-houses, the larger opening should be inside: it will afford in the two latter more light, and provide shelves for the occupants; and in the former it will present a smaller object, and make the opening higher from the outside.

"Loopholes should always be higher or lower than a man's height from the level of the ground immediately in front of them. When this cannot be effected, there should be a drop or ditch in front.

"Six feet is the length of the larger opening of the present loophole frame, which may be considered as a maximum, to be reduced according to circumstances. In towers or other works situated on high and commanding points with no level ground within range, the section described by fig. 4, Plate I., is recommended.

"These loopholes, though here represented of cast iron, may also be made of slate, or hard stone."

The above observations are chiefly applicable to the loophole when formed in brick; but when the wall is of stone, or the loophole itself set in stone in a brick wall, we are enabled, by a modified arrangement in the sides of the loop, to give much greater security to the defenders without entailing a great increase of expense.

Plate II. fig. 3. *a b c d* is a loophole to be served by two men, and requiring a horizontal range of 120°. A length of six feet for the interior opening will afford ample space for two men to serve at once. The thickness of wall is taken at 3 feet, and if the lines limiting the lateral range be produced, they will give an exterior opening of about 4 feet 6 inches.

It will now appear that if the lines *a c*—*b d* were to form the sides of the loop, the greatest protection will ensue to the defender when the opening at *e* is as small as possible.

It is necessary, however, that both men should be enabled, if required, to fire direct to the front; and a due regard to light and ventilation will not allow of this opening having a less length than 2 feet, so that the vertical area of the opening at this point will be about 2 feet by 11 inches high.

To ensure resistance against a musket-ball, and to give proper strength to the side of the loop where a soft stone is used, the thickness *f g* should not be less than 6 inches, though it will be of advantage to diminish this dimension whenever a harder material will allow of it.

The sides *g b*—*h c* forming portions of the lines limiting the lateral range of the loops, the lines *k f*—*l i* are directed on the angles *h* and *g*, and lines drawn from *a* and *d*, to intersect them at *k* and *l*, and forming an angle of 40° with *a f* and *d i*, it being assumed that a bullet will not effectually reflect from a wall at a greater angle.

On examining this construction it will be evident that no bullet can possibly reflect into the interior after striking the side of the loop, except upon the small portions *f g*, *h i*; and that while the range of 120° is preserved, the vertical space through which a bullet must pass to enter the interior is only 2 feet long by 3 inches high.*

Plate III. figs. 1, 2, and 3. A construction something similar to that just described will be found in a Paper by Lieutenant-Colonel Ord, in the eighth volume of the 'Professional Papers,' and drawings of which are given in Plate III. figs. 1, 2, and 3.

"Figs. 1 and 2 represent a simple horizontal loophole for two men to fire through. They should be, when practicable, made of cut stone throughout: if of brickwork, the head should be arched, as shown by dotted lines in fig. 4, the sides of common brick, and the holes of good hard Dutch clinkers or fire-bricks (when manufactured of a hard nature), and set in cement.

"All the four sides have one break on return, offering an important obstacle to balls from without, whether from a direct fire, or after having been reflected from some other object.

---

* The dimensions in the diagram are merely assumed to illustrate the principle, which is applicable to any variation either in the thickness of wall or size of loop.—R. T.

Plate III.

"The zigzaged loophole (fig. 3) is a plan that may be adopted with great advantage, where it is desirable, or even convenient, to have the mouth of the loophole towards the enemy, and which, in consequence of the numerous "facets" covered with sheet iron, will be found to afford scarcely less security than the plain-sided one, with the narrow opening outwards."

The following description of Lieutenant-Colonel Ord's loopholed window for defensive barracks, etc., and other buildings requiring a reasonable supply of light and ventilation, is taken from the same Paper.

"Figs. 4, 5, 6, 7, represent the loopholed window. The dimensions, when the window is to be used as a loophole, are the same as those in figs. 1 and 2, Plate III., and this is effected as follows: a wrought iron abattant, or falling shutter, is attached to the head of the iron window frame by means of a pivot or hinge, the two ends working in iron eyes or rings. The pivot is of round bar iron, with the sheet iron forming the abattant riveted to it; this abattant is lowered to the iron rests (see fig. 7), and thus forms a very complete loophole. When employed as a window, the abattant is raised by winch-handles, which are fixed on the square ends of the pivot or hinge, and, being bolted, remain continually up.

"The iron sashes are removed for action, and the loophole is then clear.

"By examining fig. 7, it will be clear that no injury can be done to the defender by shots between the abattant and the head of the window above it, unless the firing should be of such a nature that an ordinary loophole would be almost destroyed by it.

"Plates are riveted to the angles of the abattant to strengthen it. The necessity for them, and their dimensions and numbers, would be left to the discretion of the Engineer, as the strength required would of course vary according to the fire likely to be brought upon it, which would depend on the locality.

"The loopholed window should also be in cut stone, whenever practicable.

"This window may be lengthened to 6 feet when necessary, this length being the maximum."

Great difference of opinion exists in our Service with regard to the comparative advantages of loopholed fire and that of the ordinary parapet; but in sites liable to be commanded within musketry range, and unexposed to the fire of artillery, and for the close defence of the ditches, etc., of permanent works, the loophole presents most unquestionable advantages.

The general application of loopholed fire in all fortresses recently erected or in course of execution on the Continent, together with the attention paid to the direction and construction of the loops themselves, afford ample evidence on this point. It would appear that the vertical construction is almost universal in these works.* Figs. 1 and 2, Plate II., are descriptive of the arrangement of some loops at Grenoble, and form a good example for the adjustment of vertical loops upon uneven ground.

Respecting the local distribution of loops, no positive rules can be laid down where everything depends upon the nature of the site. The following observations may perhaps be of general application.

Where the loops are formed in long continued walls properly flanked by artillery or musketry, such as in the gorges of large works, they can be dispersed at longer intervals, in proportion as the command of the ground immediately in front of them is of more or less importance.

* From Captain Maurice's 'Essai sur la Fortification Moderne.'

PLAN SECTION AND ELEVATION OF A HORIZONTAL LOOP HOLE.

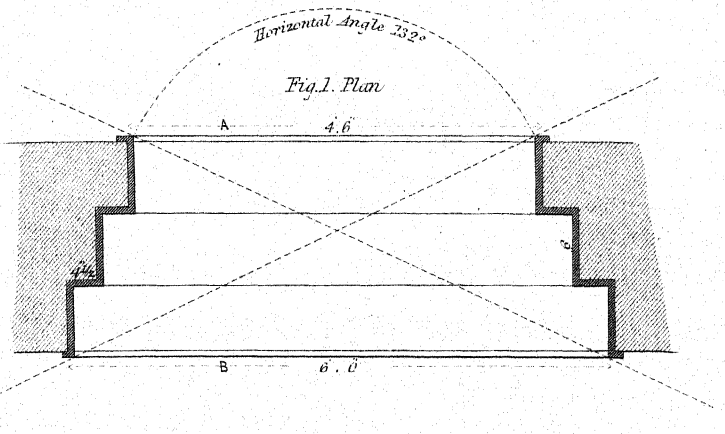


Fig. 1. Plan

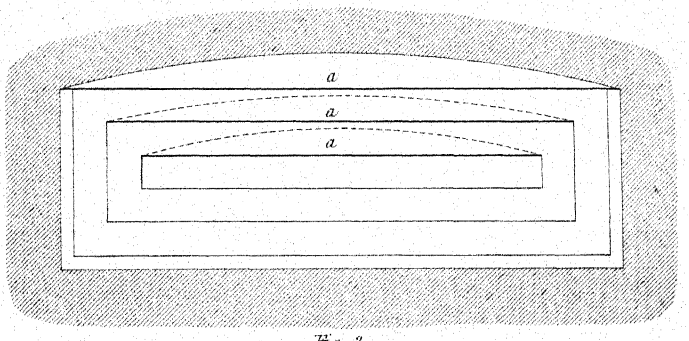


Fig. 3.

Weight of N° 1 ½ inch Iron
Cwt. 5. 0. 15

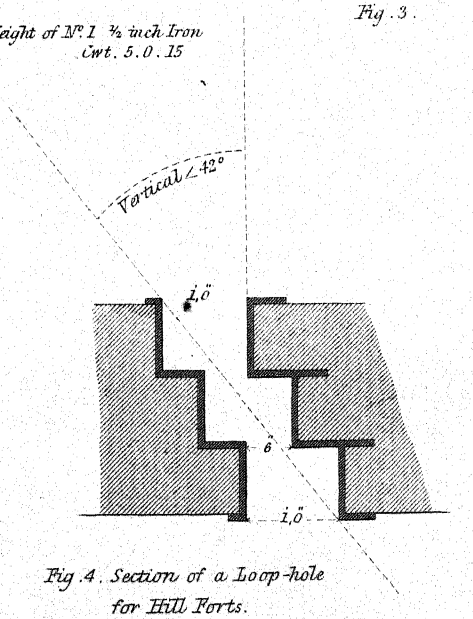


Fig. 4. Section of a Loop-hole for Hill Forts.

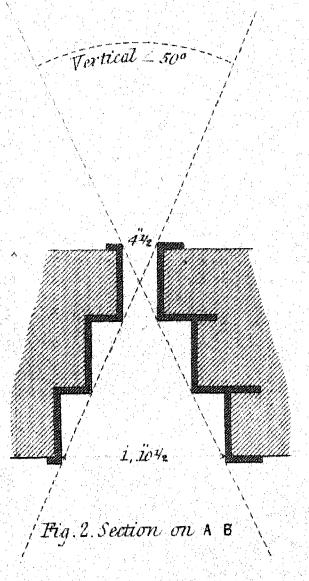
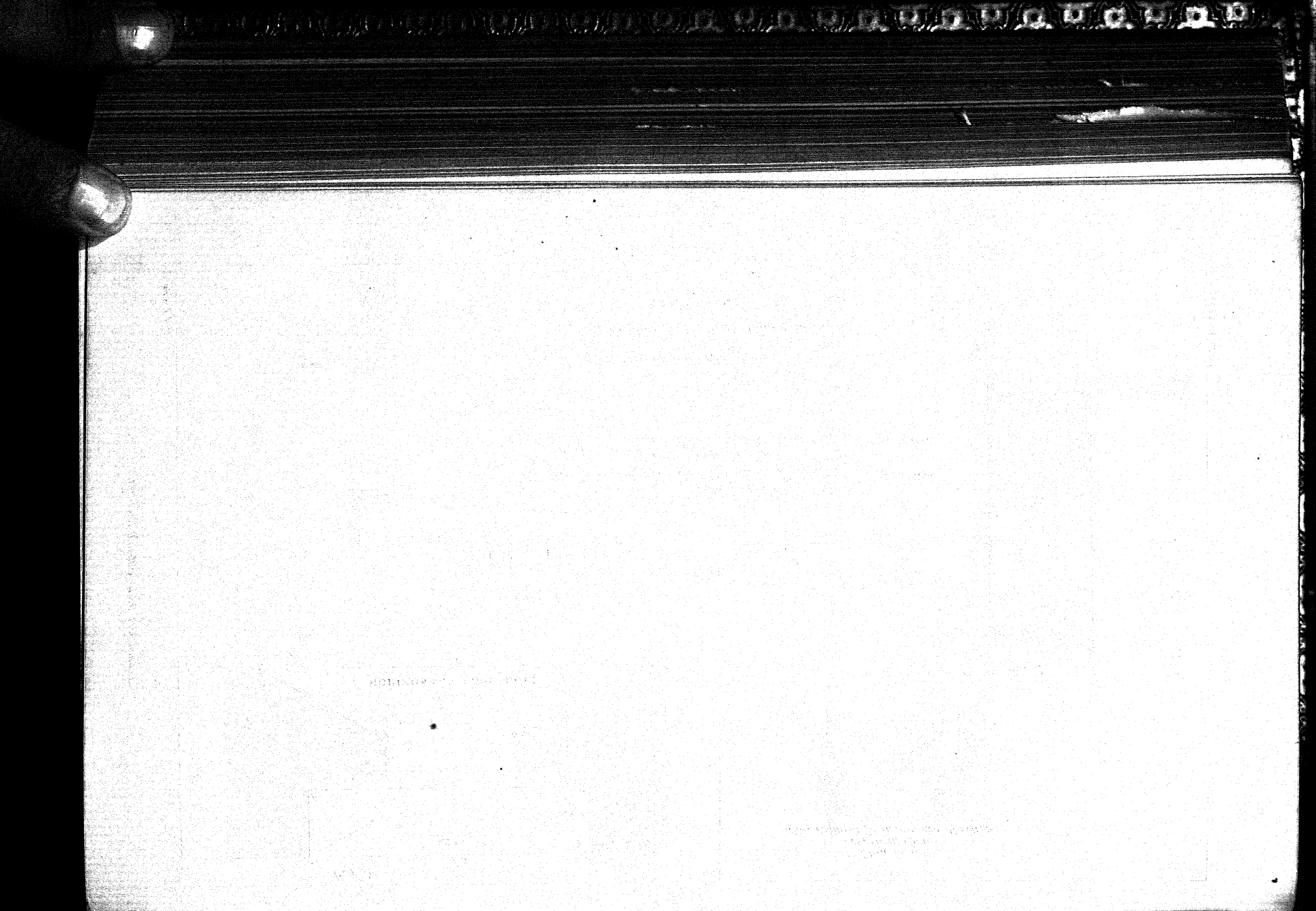
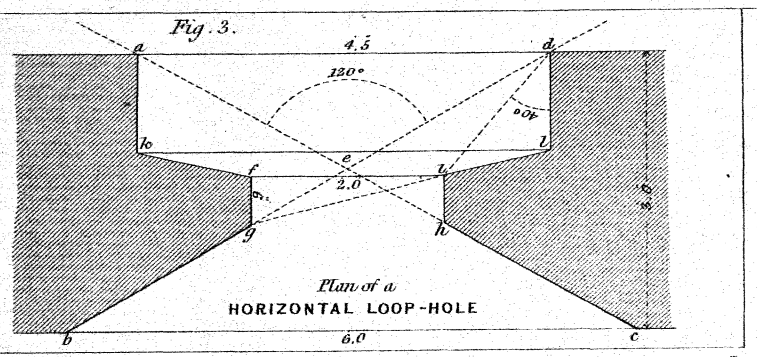


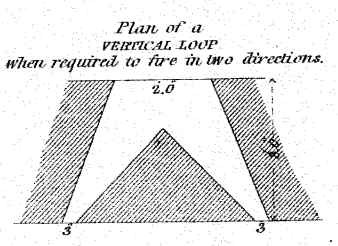
Fig. 2. Section on A B

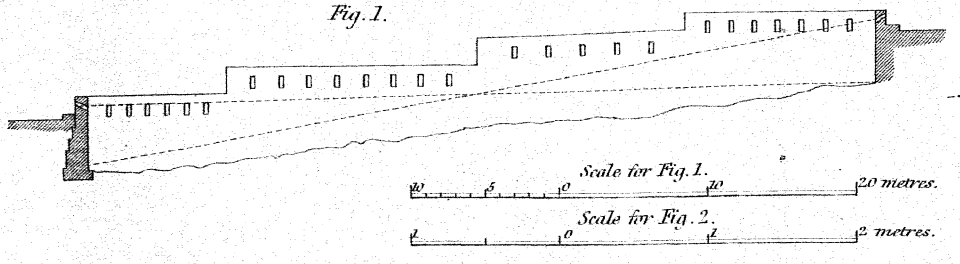
J.W. Lowry fc.

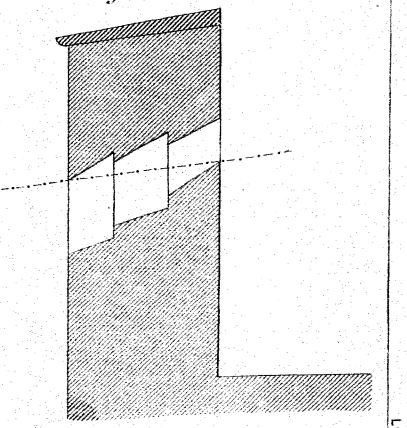
John Weale, 59. High Holborn. 1848.











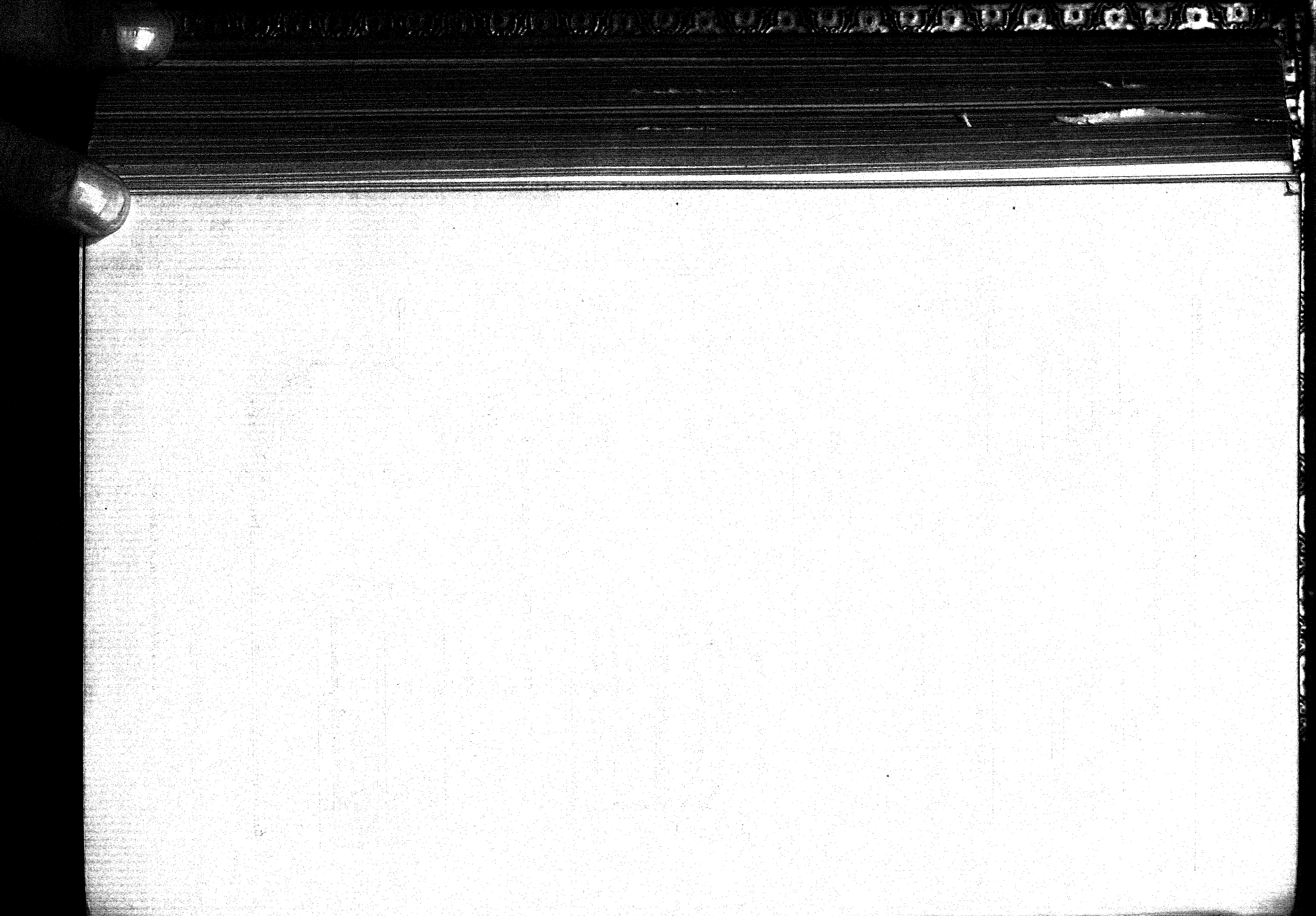
Section and Elevation

descriptive of Vertical Loops at

GRENOBLE

Lond. Lov. John Weale, 59, High Ho. Bloom. 1849.

J. W. Lowry, fc.



PLAN & SECTIONS OF HORIZONTAL LOOP-HOLES.

Fig. 2.

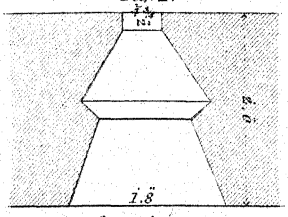
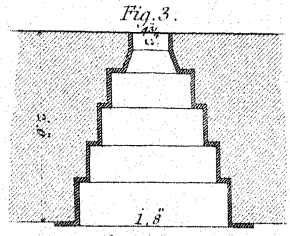
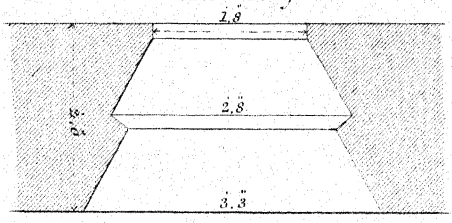


Fig. 3.

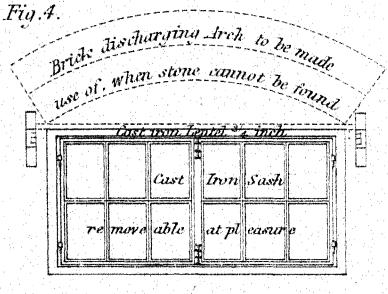


Plan — Fig. 1.



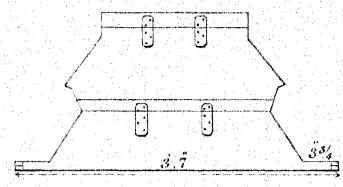
Interior Elevation

Fig. 4.



Plan of Shutter

Fig. 6.



DETAILS OF A LOOP-HOLE WINDOW.

Plan — Fig. 5.

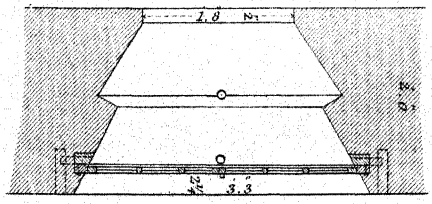
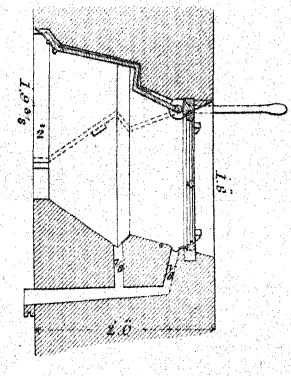




Fig. 7.



J.W. Lowry fc.

London, John Weale, 59, High Holborn, 1847.

When, however, the interval between them exceeds 7 or 8 feet, the fire becomes weak and futile; and it will be found of advantage in these instances to concentrate the loops in detached numbers towards those points most necessary to command, rather than to pierce the wall equally throughout its whole length; because, in the former case, the men will rush at once to the points most necessary to defend, and will be more under command than when detached singly at longer intervals.

On the contrary, in caponnières, reverse fires for the defence of the ditch, and where the object will be to *prevent* the passage of a large body of men, the loopholes cannot be in too great number, or too closely approximated to each other; provided always that sufficient space is allowed on each side and in rear of the loophole for one man to use, and another to load his musket, in rear of him: and it may be here observed that 2 feet 6 inches to 3 feet from centre to centre of the loops, and 6 feet width of passage in rear, are the minimum dimensions that will answer these objects.

When there are any additional obstacles in the ditch, such as the "cunette" of a permanent wet ditch, or palisades, or other impediments in the ditches of Field Forts, it is of course advantageous to concentrate a considerable portion of the loopholed fire immediately in front of such obstacles; and, indeed, the same advantage may be obtained for all loopholed walls, by the construction of abattis, etc., at a convenient distance in front of them: but every loophole should be laid out with reference to locality and its specific object, like an embrasure.

Many distinguished Officers in our Service can state from experience that no obstacle is more terrific or appalling to troops than a strongly constructed palisade or other impediment in the ditch, flanked by a powerful loopholed fire, well sustained and well directed.

Memorandum.—For the hasty construction of loopholes in the field, the reader is referred to "Field Fortification."—R. T.

DESCRIPTION OF A REVOLVING IRON LOOPHOLE INVENTED BY T. F. HAULON, CLERK OF WORKS, R.E.D.

The revolving loophole consists of three parts; the centre part A (figs. 5 and 7, see next page) is a solid metal cylinder which revolves inside a cylindrical box or casing, B, also constructed of metal, and formed of two parts having lateral flanges or plates, C, C, secured to each other by means of the screws D, D. The cylindrical box is pierced with openings, and the enclosed cylinder is also perforated for the passage of the musket or rifle, the aperture outside being made only just large enough to leave room for the free passage of the muzzle and ramrod, with a sufficient space at the top for the sight and aim.

The musket or rifle being passed through the loophole in the direction *a*, *b*, fig. 7, a command is obtained of every object within range in the prolongation of that line, and being used as a lever, laterally, the barrel gives motion to the cylinder A, so as to bring the line of fire into the direction of the lines *a c* or *a d*, which gives a sector of 60° horizontally, under perfect command. The elevation and depression of the line of fire are limited by the inward splay of the loophole. The handle and lever at E, regulate the movement of the cylinder A, thus: when the lever is moved so as to be in contact with the check at *f*, the point *b* will have moved to *d*, and when it is required to close the loophole, the cylinder is raised by means of the handle, until the lever passes over the check at *f*, and being moved round,

it drops into the notch at *g*, in which position the aperture *h i* will be at right angles to *a b*.

Fig. 5.

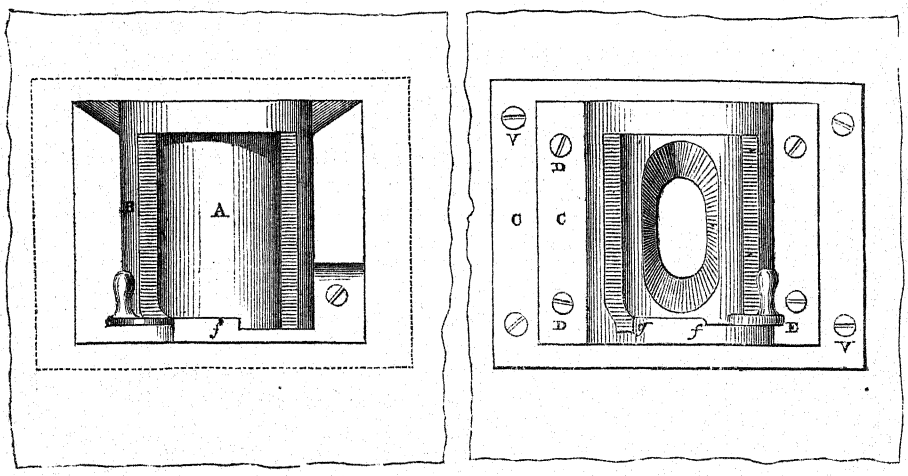


Fig. 6.

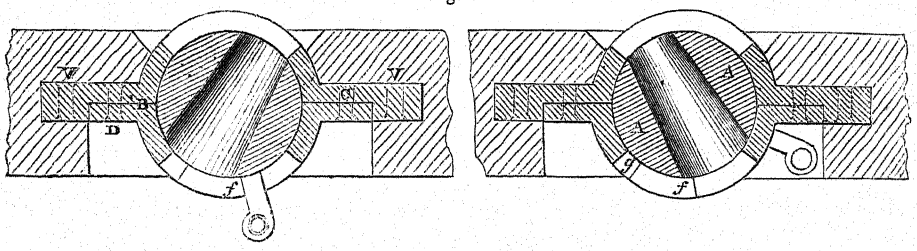
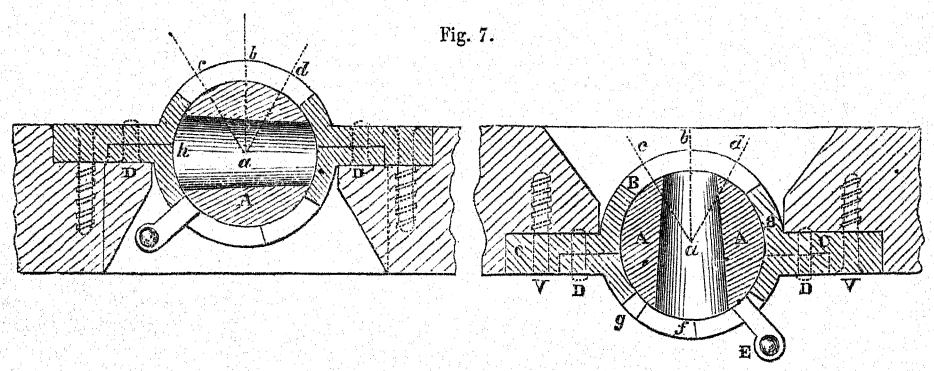


Fig. 7.



The screw holes, V, V, are intended to be countersunk on both sides, so as to afford facility for fixing the loophole from either side of the planking, etc., as circumstances may render necessary.

These loopholes may be used as simple ventilators. According to the experiments

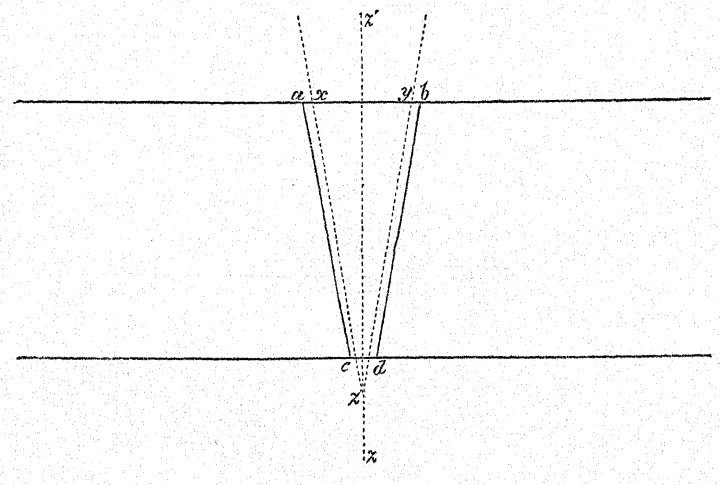
made at Chatham, it appears that a loophole of the above form, constructed of cast iron $\frac{3}{4}$-inch thick, and weighing 24lb., will bear a great number of shots from a Minié rifle without injury, and costs only 6 shillings. The opening is $2\frac{1}{2} \times 1\frac{1}{2}$ inches, its range is $75\frac{1}{2}°$ horizontally, 14° of elevation, and $19\frac{1}{2}°$ of depression.

Notes on Embrasures.—As the construction of embrasures varies without reference to localities or any specific conditions, the following observations are offered upon the principles on which they should be constructed.

We are taught that the *interior* opening at the genouillère for cannon should not be less than 2 feet 2 inches, and under the exterior crest, the width of the sole of the *embrasure* should be half the thickness of the parapet: these dimensions apply to earthen parapets that are more than 9 feet thick. When less, and the parapets are built of masonry or brickwork, the following will be found more suitable, by giving the external width of the embrasure one-third of the thickness of the parapet, plus the *interior* opening: for example, if it is 6 feet thick, the exterior width will be 4 feet 2 inches; and if 9 feet, 5 feet 2 inches. These normal dimensions give the minimum opening to the *embrasure* to afford the maximum cover to the men, gun, and carriage, and within which is the smallest space the explosion will permit, as explained by the lines *a c* and *b d*, in fig. 1. But the line of fire only extends to the triangle *x z y*; and if the muzzle of the gun is directed by the gunner beyond, he will destroy his own cover by blowing away the cheeks of the embrasure.

Although these rules are based upon certain principles, yet their application is not arbitrary, and there are exceptions which should be considered in laying out the embrasure; as for example, when the battery is exposed only to the oblique fire of an enemy, in flanks and re-entering angles, to follow the normal dimensions is contracting the power of your artillery, to the loss of flanking fire, as explained in fig. 2, where it is shown that the line *g h* and the gate *h* are not seen from the embrasures. Now as the interior may be only exposed in the directions *o*, *o*, it is unnecessary to give the minimum opening, and as this deficiency of flanking fire may expose a fortress to a coup-de-main, it is time enough to contract the embrasures

Fig. 1.



in the flanks when the counter batteries of the besiegers are about to be established. To what extent local circumstances will permit a deviation, rests in the judgment of the Engineer; but an extension to the angle *x z y*, fig. 1, will preserve the cheeks

Fig. 2.

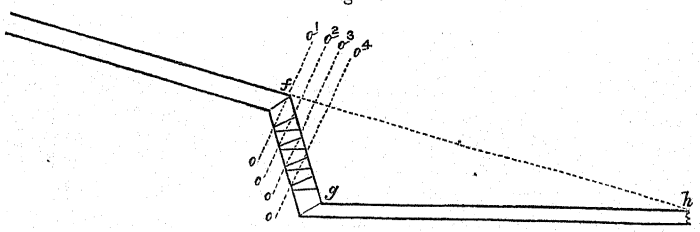
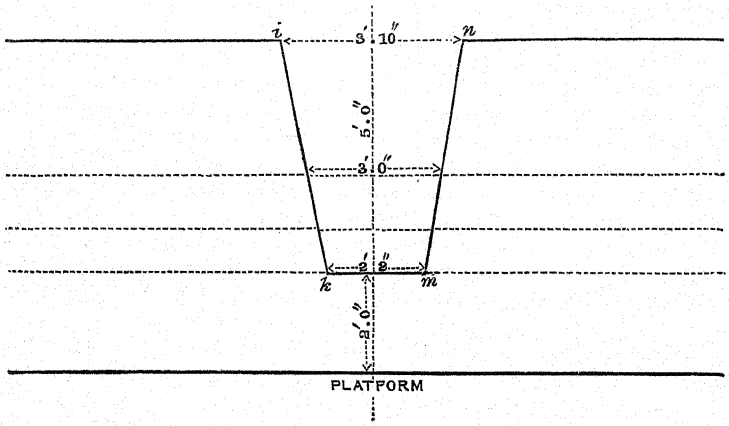


Fig. 3.



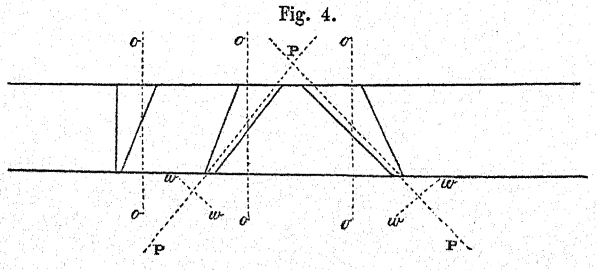
of the embrasure, and add to the scope or lateral breadth of the fire of the artillery.

When a gun mounted upon a travelling carriage to fire over a genouillère is 3 feet high, the interior opening at the genouillère may be 2 feet 6 inches, and for the dwarf traversing platform 3 feet, with a corresponding addition to the exterior width, giving the cheeks of the embrasure a slope of $\frac{1}{6}$th the height, as in fig. 3.

Oblique Embrasures are occasionally pierced in parapets for particular objects; but except under circumstances explained in fig. 2, they are objectionable, as shown in fig. 4.

When the parapets are exposed to a direct fire from an enemy, and the embrasures

Fig. 4.



are cut obliquely for some especial purpose on the lines P, P, the following difficulties occur: the parapets on the lines *o*, *o*, become too thin, and are not shot-proof; the interior is too confined, and is liable to be blown away by the firing of the guns; increased, too, because they cannot be run up on the platform, the width of the carriage and space required for the men preventing it,* as shown on the dotted lines *w*, *w*.—G. G. L.

ADDITIONAL NOTE ON EMBRASURES.

The simple form of embrasure still in general use, and which is merely an extension of the simple form of loophole, has come down to us from a remote epoch, and appears to have been adopted on the following principles: 1st, by a narrow internal opening to keep the men as much as possible under cover: 2nd, by a wide external opening to give as much lateral range as possible, consistent with the stability of the parapet. The actual range attained with a parapet of 18 feet thickness, and 9 feet external aperture, does not extend over more than 27°; but on the old system of Vauban, of placing the embrasures 18 feet from centre to centre, four guns could be brought to bear on any point of the ground before them at 89 yards, three at 67 yards, two at 45 yards; so that, considering the proper lengths of curtains and lines of defence, it may be justly said that in this, as in other arrangements of the early masters, the dimensions adopted were selected on principle; 3rd, in an 18-feet parapet, the distance from the muzzle of the gun to the cheeks need never be less than 1 foot 9 inches, as the gun ought never to be laid close to any cheek when firing parallel to it; 4th, the funnel shape, expanding outwards, greatly facilitates the escape of the elastic gases, smoke, etc.; and this is an additional reason for making that portion of a loophole, in thick walls, which is beyond the muzzle of the musket, expand outwards. It is evident, therefore, that the early form of embrasure, however simple, was not established without reason, and possesses many advantages. Occasionally, in very ancient fortresses, a casemate was formed in the parapet, and the gun advanced into it, the rear being open; a plan which had its advantage in cases where the parapet was unusually thick, and the range would have been much diminished without an inordinate extent of aperture; and, in modern times, Montalembert has adopted this arrangement, with a view to obtain increased range with diminished exposure. On his plan, the pivot of traversing platforms is, in a 6 feet parapet, carried forward to about 2 feet from the front, and a range of 60° is obtained with an opening of 3 feet 9 inches; whereas the same range would have required an opening of 8 feet, had the pivot been placed, as at Cherbourg, in the parapet, but only 1 foot 6 inches from the interior of the wall. This appears a great advantage, but there is a disadvantage connected with it in actual service which has been overlooked; namely, that the wall must be cut away in a corresponding degree in the rear, to permit the gun to traverse so that the carriage is brought, when trained to either side, within the parapet; and even after recoil, the inconvenience of loading must be considerable. Montalembert intended however his embrasure merely for casemates; but Lieutenant Penrice proposes its application to parapets of greater thickness, in order to replace entirely the old embrasure; and in that case the difficulty pointed out would be still greater, and the extent of parapet in the rear required to be cut away, in order to admit of ready manipulation, much augmented.†

In the ninth volume of the 'Corps Papers,' it has been proposed to modify still further the opening of Montalembert's embrasure, by adopting a cheek of more than one plane, so arranged as to prevent a shot entering by ricochet from its surface. On

* Some of these evils may be remedied by indenting the parapet.—*Editors.*

† The parapet is also greatly weakened by this means.—*Editors.*

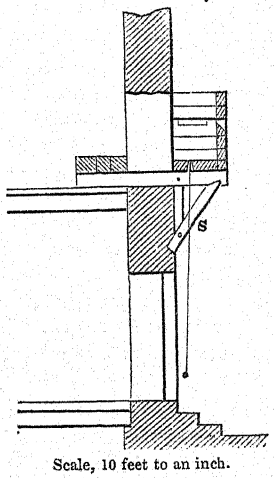
this latter point, there is much misapprehension, from confounding the ricochet angle with low charges with that of high charges; and as embrasures are more exposed to the fire of guns with full service charges than to the true ricochet fire with low charges, the precaution directed against the latter is unnecessary against the former. By the experiments carried on at Metz, it has been shown that a 12 lb. French shot with a charge of one-half its weight began to ricochet only at 20°; and with one-third, only at 25°; and that in each case there is penetration to the extent of nearly 6 inches, the ball being reflected at a considerably higher angle by scooping out the masonry, and in so doing, losing its velocity to such an extent as to be capable of doing little subsequent injury. The great evils are, the ruin of the embrasure, and the destructive effects of its splinters; and these are perhaps best guarded against by preserving the simple earthen embrasure, strengthening only the throat by a concrete backing extending inwards for about 3 feet, to receive the shock of the shot after it has penetrated the earth. Without therefore wishing to check improvements in loop-holes, or in embrasures, a doubt may be fairly expressed whether the advantages expected from the more complicated forms proposed are really equivalent to the disadvantages which attend them in service; and whether the simple loophole and embrasure, properly applied and arranged, have not yet a practical superiority over those proposed to replace them.—J. E. P.

M.

MACHICOULIS.*—*Machicoulis galleries* are constructed over the entrance to a building or enclosure, or over parts where an opening is liable to be effected by crow-bars, or by firing a charge of powder, etc. Their use is to enable a vertical musketry fire to be directed upon the enemy outside, and to facilitate pouring down melted lead or other missiles upon them.

Blockhouses are often constructed with the upper stories projecting all round, so as to afford them this means of defence (*vide* "Blockhouse"); and in the Article on "Guerites" will be found an account of the application of machicoulis galleries to salient angles.

Fig. 1.—Section of a Machicoulis Gallery.



Scale, 10 feet to an inch.

When placed at one side of a building or enclosure, an opening large enough for a man to get through is made at least 8 feet above the ground outside, and holes are also broken through the wall on each side, level with the bottom of the first, to admit of strong beams being thrust through, so as to project horizontally 3 feet, if possible, outwards; the outer ends of which must be supported by struts (marked S in Fig. 1), resting against notches made in the wall, or by securing their inner ends by heavy weights or ties; across these beams planks are laid, forming a floor, with an interval 4 inches wide for firing, and dropping grenades through; and round the front and sides of this platform a parapet of wood or of iron plates must be built, so as to cover the men whilst firing: in this loopholes

* By Lieut.-Colonel Bainbridge, R.E.

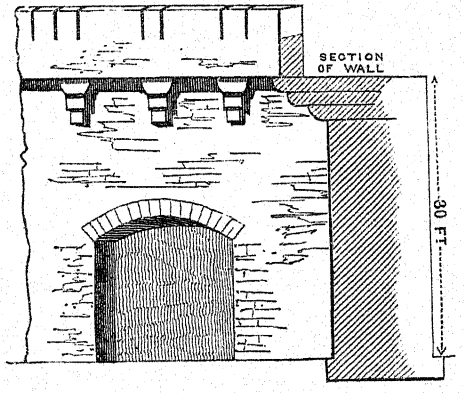
may be formed, and it may be made of oak planks 2 inches thick, covered with wrought iron plates $\frac{1}{8}$ inch thick. The thicknesses of other materials required are given in the Article on "Barricades."

An ordinary iron balcony forms a very good framework for a machicoulis gallery, as shown in Plate I., "Defence of Posts;" and it has been suggested that by fixing iron shutters in front of embrasures, so as to form a salient angle, and projecting beyond the wall, they may be used to fire from upon an enemy at the foot of it.

Machicoulis galleries, built of brick resting upon stone corbels, are often applied to Martello towers for the defence of the doors, or over re-entering angles of fortification when they are badly flanked; but they are liable to be destroyed by a single cannon-shot, unless their walls are supported by massive arches, and made 3 or 4 feet thick.

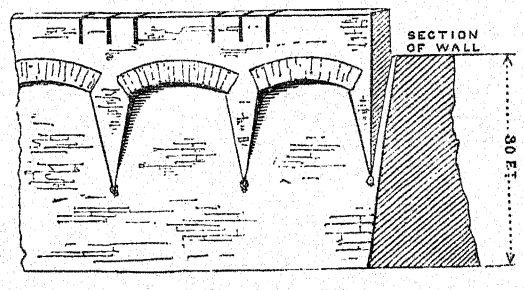
Note on Machicoulis—Frequently used in the defence of escarps and towers;

Fig. 2.



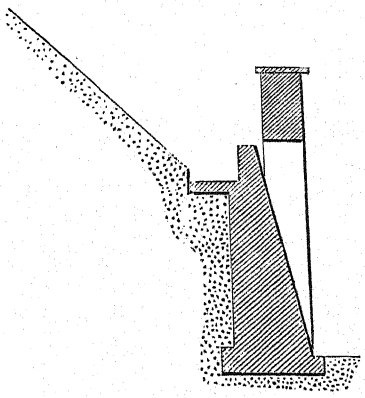
St. George's Tower, at Windsor Castle, is an example. Colonel Nelson, R.E., has applied them to a project in the 7th volume of 'Professional Papers,' in the Article on Coast defences; and the annexed diagrams will explain how they may be applied advantageously to lines of walls on the edge of precipices, banks of rivers, and on sea lines, where it is desirable to see the foot of the walls in particular circumstances, when they are not exposed to the fire of heavy artillery, and the ground for the line of wall is too narrow to admit of flank defence. See figs. 2 and 3.

Fig. 3.



Capitaine Emile Maurice, in his '*Essai sur la Fortification Moderne*,' gives a profile showing the application of the machicoulis to the chemin des rondes, as in fig. 4.

Fig. 4.



The entrances of towers and small forts without flanks should each have a machicoulis over the gateway or drawbridge; for small garrisons are frequently intimidated by the miner fixing a petard or bag of powder to the gate or bridge, and are inclined to surrender without sufficient cause. These works should always have a supply of filled sand-bags ready to be placed in the internal recesses of the doors and windows, which would lessen the ill effect of the explosion.

MAGAZINE.*—*The Construction of Gunpowder Magazines* should have reference to their object, whether they are required as a depôt, entrepôt, or for the supply of coast batteries, forts, or fortresses: in the latter cases they should be bomb proof. It is conceived that, if they hold 500 rounds per gun, that quantity will be the most convenient for supply; and no magazine should contain more than 1000 barrels.† In a fortified place, armed with 100 pieces of ordnance, this arrangement would require five magazines.

When it is found convenient in fortified places to place the magazines in detached sites, such as the centres of empty bastions, or open spaces within the enciente, for the preservation of the powder, previous to investment or to a probable attack by sea or land, there are various ways of constructing them: among the earliest patterns followed are those of Vauban and Belidor.

Major-General Fanshawe appears not to approve of Vauban's or Müller's external buttresses, but would prefer having the external lines free from *corners*, which always generate damp, and instead would place the buttresses within, making the arches extend to the outside of the end walls. When a series of parallel apartments are necessary, Major-General Fanshawe prefers their being connected by groined arches, and he is an advocate for as much areal capacity as possible. Those at Tipner and Devonport are an example of this description of magazine.

He considers likewise that no building, but especially a magazine, should be erected over a pit or excavation, unless there be a still lower and well-drained area around the building itself. Whitewashing with lime is objectionable, as lime attracts moisture; but if there should be causes of internal damp, small parcels of lime may be placed, to attract the damp, near the ventilators.

Major-General Pasley, in his work on Elementary Fortification,‡ observes that "powder magazines are usually provided with double doors and window-shutters, which are made of thick materials and covered with copper. The air-holes, both inside and out, are covered with copper and copper-plates having a great number of

* Compiled by Major-General Lewis, C.B., R.E.

† In depôts they are sometimes made to hold 10,000 barrels.—*Editors.*

‡ Second edition, p. 372, etc.

small holes perforated in them. No iron or steel is ever permitted to be used in the construction of powder magazines.

"Sometimes magazines have been formed with groined arches, that is to say, with two sets of arches of equal height, or nearly so, intersecting each other at right angles. In this method there is a saving of materials, and a greater interior space may be gained, because, instead of intermediate pier walls, extending in a continued line from one end of the magazine to the other, as in the old mode of construction, there are only small pillars of about 4 or 5 feet square at the utmost, which may be placed at considerable intervals apart, and from which the groined arches spring in contrary directions. This construction has however been seldom used, being less simple and weaker than the former mode.

"With respect to the roofs of magazines and other bomb-proofs, which are not covered at top with some feet of rubbish, like those of casemates, it is prudent on that account to add to the thickness of masonry, in order to make them equally secure against shells; but the same precautions against damp are unnecessary, for the common slates or tiling, etc. used in dwelling-houses, are quite sufficient, provided that the ridges and gutters are leaded. Much however depends upon the pitch of the roof, which ought to be rather steep than otherwise; the low pitch recommended by some architects, for the sake of beauty, being unfit for northern climates."

Powder magazines have lately been erected in Germany which have the buttress within: this mode of constructing magazines appears to have some of the advantages of groined arches, without the disadvantages alluded to by General Pasley.

When magazines are isolated, for the advantages of a free circulation of air, and preservation of the powder in time of peace, the German construction should be adopted, to hold 4000 or 5000 barrels, which are to be distributed, when an attack is threatened, into small magazines. The late Colonel Williamson, of the Royal Artillery, in his Notes, as published in the '*Minutes of Proceedings of the Royal Artillery Institution,*' observes: "In cases of siege it is usual, and indeed necessary, to place splinter-proofs and traverses before the doors of the principal magazines of a fortress; and the windows, especially those on the side of the country, are frequently built up or shut up with logs of timber. In this case the magazines are very dark; and indeed many magazines, situated in the towers of old fortifications, have scarcely any light at all; it is consequently necessary to make use of Muscovy lanterns, which should invariably be held by a non-commissioned Officer or some trusty person. The door of the lantern should never be on any account opened in the magazine; and the candles should be of wax, as when of tallow they frequently require snuffing. Splinter-proofs before the doors make them very dark, and a person upon entering fancies himself in complete darkness; but after a short time things are readily distinguished. The men therefore at work inside of the magazine ought always to remain inside, and those outside ought never to enter, but to lay the barrels down or receive them at the doorway, besides a third party stationed at the entrance, and communicating with the other two.

"Powder magazines are usually divided into certain spaces, called bays, by wooden posts or uprights connected together at top and bottom by open framework: passages are left between the parallel bays and at the ends, of 2 feet 2 inches wide. In all powder magazines it ought to be an invariable rule, that one of the bays be empty, for the sake of shifting the powder, which ought to be frequently done. The empty bay is to receive the barrels from a full bay; and this bay, just emptied, is to receive those of another full bay, and so on; so that the bay last emptied will remain so. When shifting the powder, the situation of the barrels must be changed: those which were at the top tier are placed in the bottom tier, and those which were at the bottom

in the top, by which means they are relieved from the great pressure which was on them when they were lowest."

Since the introduction of concrete in foundations, it is now the practice in building powder magazines, or in renewing the flooring, to spread concrete throughout,* so as to prevent damp from rising from the ground, and to build the walls which bear the flooring joists upon it, to such a height that a current of air may pass between these low piers. The ground between the walls of all magazines and the surrounding wall should be paved and kept clear of weeds.

The position of Gunpowder Magazines, and the Security of the Powder, must also have reference to the wants of the Service: for depôts, entire separation from other buildings, and freedom from all risk of fire, are the important considerations. The next points are the conveniences of transport by *sea* or *land*. It does not appear essential that the magazines for depôts should be arched: the depôt at Marchwood has a timber roof like a store, and the buildings are dry, and the powder in excellent order. The roofs of magazines of this description should be of one span, to avoid lead gutters, as they frequently crack, and admit rain and snow: the doors should be placed north and south, the windows east and west, and open inside, with wire-guards outside: the spouting should be of copper, and not of wood. Some prefer that barrels of powder should contain 90 lbs., and not 100 lbs., as now ordered, as the former quantity allows the powder to fall back into single grains every time it is moved. Magazines should never be opened in rainy or damp weather, if it can be avoided.

The Position of Magazines in Fortresses.—Some difference of opinion exists among Artillery Officers on this subject. It is conceived that magazines for the general supply of a fortress should be detached from the ramparts, in an airy site, in the empty bastions, in a work entirely enclosed by them; or in maritime places, in sites contiguous to those for the embarkation and disembarkation of stores; and that during a siege the powder should be placed under the ramparts, perfectly secure from an accidental explosion from the enemy's artillery, or where, if exploded, the defences may not be injured, the passages to the magazine being well blinded.

Expense Magazines, as explained in the notes of the late Colonel Williamson, of the Royal Artillery, published in the '*Minutes of Proceedings of the Royal Artillery Institution at Woolwich*,' should be "much smaller than depôt magazines: when possible, they should be bomb-proof, but in general they are not so. In a fortress, there ought to be an expense magazine to each bastion and battery, though this is not always the case: they generally only contain made-up ammunition, that is, cartridges for the ordnance in the bastion or battery, at the rate of so many rounds per gun, to which are to be added the tubes, port-fires, etc.: sometimes the side-arms and case-shot, etc., are kept there, and are usually under the care of the Artillery Officer in charge of the district. They are often made under the earthen ramparts of fortifications, with a cut or passage made into them in the interior slopes: they ought not however to be made until a siege be apprehended, for as they are only temporary, and constructed of wood-work, they are often damp, and the wood decays.†

"When there is only one expense magazine for several batteries, or when a battery consists of only two or three pieces, it is usual to have on each battery *Portable Magazines:* they are wooden boxes covered with canvas, and of such a size as to be

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* A thin coating of asphalte should be spread over the footings of all the main walls, cross walls or piers, and dwarf walls.—*Editors.*

† This description of expense magazine may be constructed of masonry, and thus become permanent, although only adapted for a temporary supply.—*Editors.*

carried from place to place; they are sometimes on wheels, and sometimes without: in the latter case, they ought always to be placed on skidding, to keep them off the ground, besides having ledges on their bottoms. In these is contained a certain number of cartridges for each piece in the battery, together with tubes and port-fires: the side-arms, handspikes, etc., are in such case placed in a small shed built against the interior slope of the epaulement, to defend them from the weather."

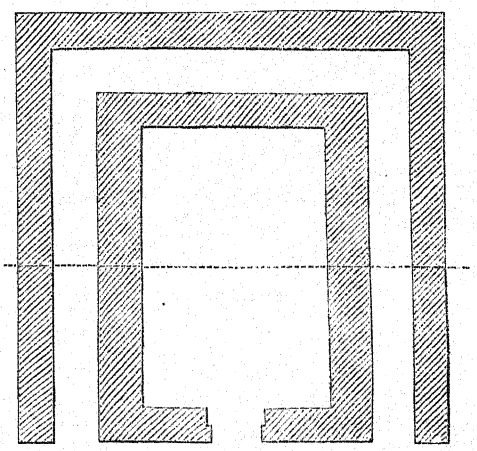
In conclusion, it should be explained that Magazine, as a military expression, always means *Powder Magazine;* and when military buildings contain other materials, they are termed *Stores.* G. G. L.

Note.—When magazines are placed in an exposed position, or in any situation which renders it necessary to surround them with a mass of earth, they should be built with a passage or aisle about 2 ft. 6 in. or 3 ft. wide, round the sides and rear, covered by the same roof as the body of the building, as in the annexed diagrams.

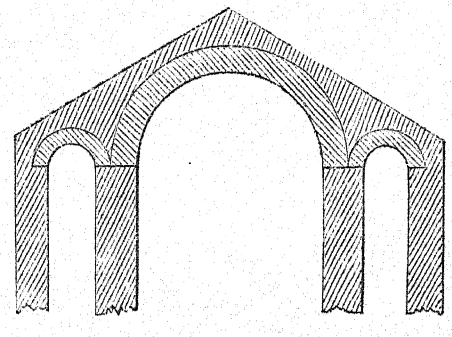
In the case of an expense magazine, these side passages may be used for the side-arms.

In all large magazines a travelling crane should be arranged for the purpose of moving the barrels from one bay to another; and where several such magazines are together, traverses should be erected between them of sufficient strength to resist an explosion. C. R. B.

Plan.



Section.



MANŒUVRES OF CAVALRY.*—The British Cavalry of the present time is composed of two kinds, "Heavy" and "Light."

1st. The "Heavy Cavalry,"—Cuirassiers, Dragoon Guards, and Dragoons.

2nd. "Light Cavalry,"—Light Dragoons, Lancers, and Hussars.

* By Lieutenant and Adjutant Haviland, 2nd or Queen's Dragoon Guards.

The heavy cavalry should be employed in actions of shock, and movement en masse.

The duties of light cavalry should be, reconnaissances, outposts, pickets, patroles, etc.

The instructions for cavalry should be concise and simple, and entirely founded on the practice of actual warfare; for the more theory is identified with practice, the better.

The dismounted drill of the dragoon is the means of teaching and preserving the recollection of the mounted manœuvres, without harassing the horses, and is now very properly executed by the same words of command.

There are three distinct paces in cavalry; viz. the "walk," about four miles per hour; the "trot," of about eight miles per hour; and the "gallop," of eleven miles per hour.

1st. The "walk," which is the pace of route, and when on service, ought not to be exceeded, it being sufficiently quick for the movements of any army (unless upon an emergency), as the average weight of a dragoon is upwards of 18 stone, not including rations and forage, which, for one day's consumption, is about 28 lbs.

2nd. The "trot" is the best pace for manœuvre: it enables a column or line to preserve its ensemble.

3rd. The "gallop," which embraces the "charge," is the pace of action, or for quick formations preparatory to it; at this pace the horse is most distressed: it should not be applied to the general purposes of manœuvre. The rate of pace of the "charge" should not exceed the full speed of the slowest horses, as it is from the uniform velocity of the attacking body that its greatest effect is to be obtained. At the instant of the concussion, the horse (although in hand) should be pressed forward.

There are three different modes of attack; viz. the Attack in Line—en Echelon—and in Column.

1st. The "attack in line" is the form of attack against cavalry: its movement must be progressively quick; it must "walk," "trot," "gallop," and "charge:" the latter must take place at a distance of 50 or 60 yards from the enemy; and as *support* is necessary to complete the success, or cover the failure, it should be formed as follows:

The support before the line advances to attack, should be in two close columns in the rear of the flanks of the attacking line; and on the line advancing, it should advance in open column of troops from the leading squadrons: in the event of a successful attack, the open columns continue to advance and wheel in upon the flanks and rear of the enemy. If the attack fails, the columns are in position to cover the retreating line, and can frustrate any attempt to outflank.

2nd. The "attack en échelon" is the best method of attacking batteries, and the easiest way of gaining a flank;—it also hides your intention from the enemy. The whole not being engaged (at the same moment), the rear échelons serve as a reserve, and deter an attack on the leading échelons, from the danger the enemy would be in of being taken in flank by the échelons that have not entered the line of attack.

3rd. The "attack in column" is against infantry,—the most difficult and dangerous of cavalry operations: it should be made by squadrons in succession, and not attempted against squares of infantry until the fire of artillery has thrown the enemy into disorder.

A column of squadrons attacking squares should retire by *threes* from the outward flanks, the moment after the charge is made, so as to clear the front of the next charging squadron, and not to impede the impetuosity of its attack: the retiring

squadrons should form in the rear of the *reserve*, and *never* upon the support, which would be thrown into confusion by a body in disorder falling back upon it.

Formations for attack should be in three distinct bodies; viz. for the *attack*, the *support*, and the *reserve*.

1st. The first body should be formed in line, and should be about one-third of the whole strength.

2nd. The "support" may be in open column, in rear of the flanks of the first; or in line.

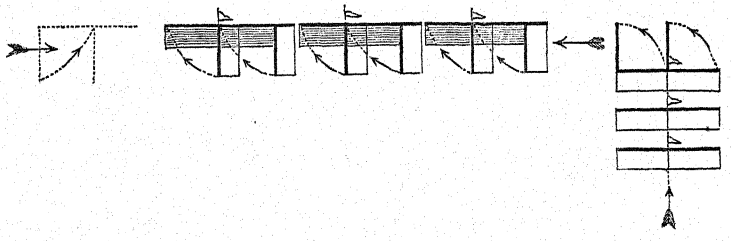
3rd. The "reserve" should be either in close column of squadrons, or in double open column of troops (regimentally).

With respect to the manœuvres of a regiment of cavalry, they are so well defined in the '*Regulations for the Instruction, Formation, and Movements of Cavalry, dated Horse Guards, 1st January*, 1844,' that nothing more can be desired, except some orders relative to Manœuvres in Brigade, of which nothing has as yet been promulgated. The following movements were found necessary and useful by the brigade of cavalry stationed in the summer of 1846 in Dublin.

1st. The cavalry in two columns of squadrons at quarter distance, on each flank of the infantry (the infantry being in contiguous columns of regiments). The right column of cavalry being left in front, and the left column right in front, is ordered to form line in front of the infantry (to mask its deployment); both columns will advance perpendicularly to their front, and then take ground in open column of troops inwards from the leading squadron (of each column) in succession, and, when the leading troops arrive within wheeling distance, "wheel into line."

See diagram of the right column, marked Fig. 1.

Part of left column. Fig. 1.



REGIMENTAL COMMANDS FOR THE MOVEMENT.

Commanding Officer—{Take ground in open column of troops, to the left in succession from the 3rd (the leading) squadron.

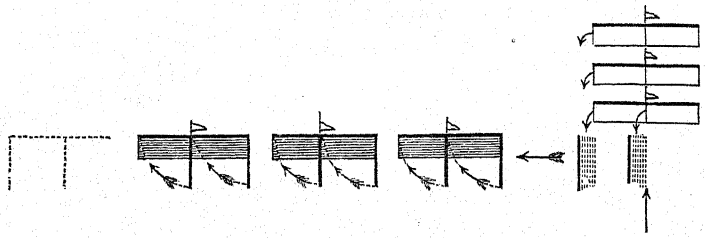
Leader of 3rd Squadron—Troops left wheel.

Leaders of remaining Squadron—Advance, and Troops left wheel, when their squadrons arrive at the ground the leading squadron marched from, and follow in open column.

2nd Ex.—The cavalry in two columns of squadrons on the flanks of the infantry, as before, with this difference: the right column, *right* in front, and the left column, *left* in front; both columns advance, and then take ground in open column of troops inwards, from the *rear* squadron of each column in succession, and wheel into line when the heads of each column arrive at proper distance.

(The right column taking ground from its rear squadron.)

Fig. 2.



REGIMENTAL COMMANDS FOR THE MOVEMENT.

Commanding Officer—By threes take ground to the left in open column of troops in succession from the 3rd (the rear) squadron.

Leader of 3rd Squadron—Threes left, Leading threes (heads of troops) left wheel—Halt—Front—Forward, (followed in the same manner by the other squadrons in succession.)

3rd Ex.—The cavalry being in line in front of the infantry, is ordered to retire in open column of troops, and form close column in rear of the flanks of the infantry.

The cavalry will retire from both flanks, and when the head of each open column has passed the infantry line by about 50 yards, they will receive the order to "Form close column to the rear on the leading troop."

Fig. 3.

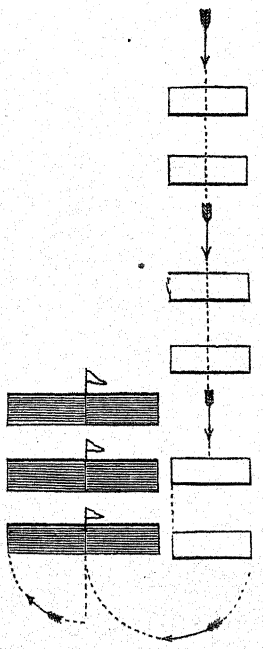
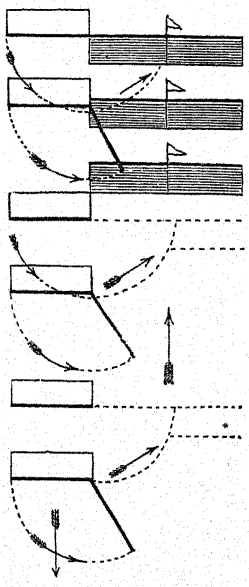


Fig. 4.



The Regimental commands to execute the manœuvre would be,—

Commanding Officer—Right about—Form close column.

Squadron Leaders—(Repeat the command).

Right Troop Leader of the 1st Squadron— Right troop, right about wheel—Forward—(the depth of the column)—Halt.

Left Troop Leader of the 1st Squadron— Right wheel, (when at the rear rank of the preceding troop)—Forward—(pass along the rear) Right wheel—Halt—Dress up.

The other Troop Leaders—The same in succession. The column would then stand right in front.

Ex. 4.—But if the right column (retiring right in front) is ordered to form the close column to the rear *left* in front, it must be done in the following manner on the rear troop. *Vide* diagram No. 4.

The right column retiring, and forming close column to the rear, *left* in front.

REGIMENTAL COMMANDS.

Commanding Officer— Form close column to the rear on the rear troop.

Squadron Leader—(Repeat the command).

Left Troop Leaders—Left troop, left about wheel.

The Leader of the Rear Troop—Halt—Dress.

The other left Troop Leaders (after wheeling about)—Forward.

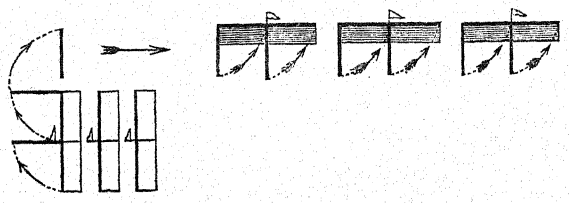
Right Troop Leaders— Three-quarters left about wheel—Forward—Trot—Left forward—and on joining the left troop, Walk—until they close to the front—then the

Squadron Leaders—Halt.

Ex. 5.—The right column of cavalry is ordered to take up a new position to the right, but to the *rear* of the infantry.

The close column standing right in front will retire in open column right in front.

Fig. 5.



REGIMENTAL COMMANDS FOR THE MOVEMENT NO. 5.

Commanding Officer—Retire in open column from the right.

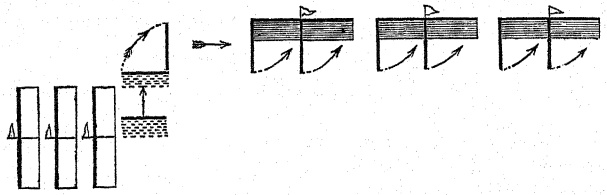
Leader of 1st Squadron—Troops right wheel—Forward.

And when the right troop has passed the reverse flank by one horse's length, its Leader will give the word Right wheel—Forward. The left troop follows the right, and the remaining squadrons wheel *off their ground* in succession, and

follow the 1st squadron in open column of troops; and when the open column arrives at the position ordered to be taken up, it will wheel (left) into line.

Ex. 6.—If the right column of cavalry should stand left in front, when ordered to take up a new position to the right, but in rear of the infantry, it can easily be executed (without countermarching) by threes taking ground in open column to the right in succession from the rear squadron, and changing direction to the right.

Fig. 6.



REGIMENTAL COMMANDS.

Commanding Officer—{Retire in open column, right in front, in succession from the rear (1st) squadron.

Squadron Leader of the rear (1st) Squadron—{Threes right—Leading threes (heads of troops) right wheel—Halt—Front—Forward.

As soon as the word Forward is given by the Squadron Leader, the Leader of the right troop will give the word Right wheel—Forward. The other squadrons will proceed in the same manner in succession, which will bring the whole into open column right in front;—and when the column arrives at the position ordered to be taken up, it will "Wheel into line."*

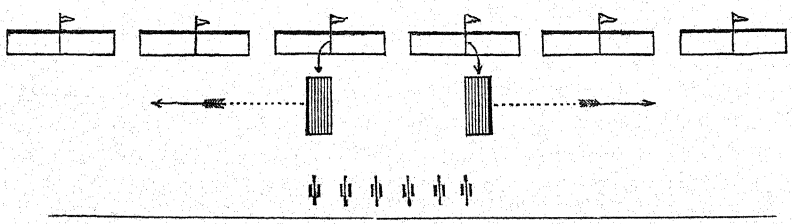
In the 'Cavalry Drill-Book,' page 192, Movement No. XI. from line, the troops wheel about to execute the movement; but supposing a line of cavalry masking artillery was ordered to retire in column of troops from the centre in succession by the rear, to quickly clear the front of the guns, it could not be done by the troops wheeling about; but it can be by the following method (which would allow the artillery to come into action): viz. "By threes open column of troops from the centre in succession by the rear."

Commands.

Left Troop Leader of the right wing—{Left troop—Threes right—Leading threes right wheel—Halt—Front—Forward.

Right Troop Leader of the left wing—{Right troop—Threes left—Leading threes left wheel—Halt—Front—Forward.

Fig. 7.



* In detailing the foregoing manœuvres, the diagrams and commands are laid down for the right wing of the brigade; of course it will be necessary to substitute *left* for *right*, and *right* for *left*, for the *left* wing.—F. H.

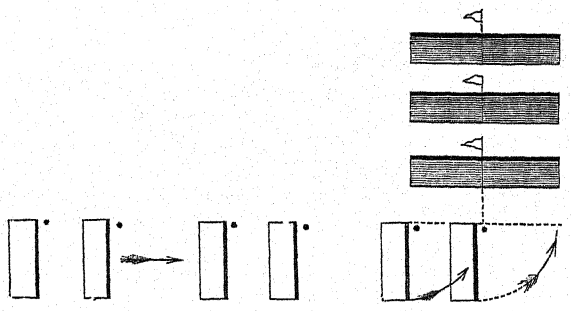
Each troop will follow in succession in the same manner; the right wing will be a column left in front, and the left wing a column right in front: then, by changing the direction of the heads of the column, the cavalry would be en route to get under cover of the infantry, or be in position to re-form line to any front.

The following manœuvres are useful as Regimental Movements, but not laid down in the '*Instructions for the Cavalry.*'

1st. A regiment being en route in open column of troops right in front, is required to form a close column to its pivot flank.

To the pivot flanks form close column.

Fig. 8.

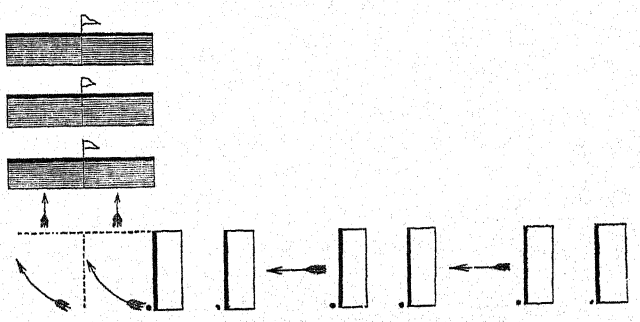


Leader of the 1st Squadron— {Left wheel into line—Forward (move up the depth of the column)—Halt.

Leaders of the other Squadrons, as they arrive upon the ground upon which the 1st wheeled into line— {Left wheel into line—Forward, (and when at proper distance from the preceding squadron) Halt—Dress.

To the reverse flank form close column.

Fig. 9.



Leader of the Right Troop of the 1st Squadron— {Right wheel—Forward (the depth of the column)—Halt—Dress.

Leader of the Left troop of the 1st Squadron— {Right wheel (after passing along the rear of the right troop) Forward—and—Halt, when on a line with the right troop.

The other Troop Leaders—The same in succession.

MANŒUVRING HORSE ARTILLERY.*

The following extracts form part of a "Code of Instructions for the Exercise and Movements of the Royal Horse Artillery," drawn up in obedience to the directions of the late Lieutenant-General the Right Honourable Sir James Kempt, Master-General of the Ordnance.

The principles which govern the application of Horse Artillery, as well as the encampment, the embarkation and disembarkation of troops, etc. etc., being the same as with Field Artillery in general, are not repeated in the following code, as they may be found on reference to the '*Instructions and Regulations for Field Battery Exercise*,'† of which each Officer in the regiment of Artillery is required to have a copy in his possession.

GENERAL PRINCIPLES FOR THE MOVEMENTS OF HORSE ARTILLERY.

PRELIMINARY OBSERVATIONS.

The same general principles regulate the Manœuvres of Infantry, Cavalry, and Artillery: as the infantry is however the main body of an army, it must govern the movements of the other Services, and therefore this exercise has been prepared in conformity thereto.

The plan of the '*Regulations for the Field Exercises and Evolutions of the Army*,' and of the '*Cavalry Regulations*,' has been followed, and the general principles, movements, and words of command have been adopted as far as the difference between the Services rendered it expedient.

Horse artillery should, as frequently as possible, be exercised with cavalry and infantry, that they may acquire the habit of manœuvring in a confined space, without embarrassing the troops, who move as if no artillery were attached to them. Several of the manœuvres in the exercise have been introduced with this view.

A troop of horse artillery can perform nearly every manœuvre of a brigade of cavalry or battalion of infantry, but many of the movements are more a matter of show than of real utility. The evolutions of several troops acting together are on the same principles as those of one troop.

Whenever several troops can be assembled, the opportunity of exercising them together should never be neglected; eight or ten days' drill will be attended with the greatest benefit to both officers and men; will enlarge their ideas, and show them how easily considerable bodies of artillery can be moved: it will also accustom them to preserve their distances correctly, which is most essentially necessary, particularly when artillery is acting with other troops. This must at all times be strictly attended to.

The horse artillery, without being obliged to follow, step by step, all the manœuvres of the cavalry or infantry, proceeds to the execution of the orders it receives in the easiest and most expeditious manner. The proper employment of that particular arm, according to the situation of the ground, and the circumstances of the case, must ever be kept in view in all orders issued to it.

In cases of parade or review, it is absolutely necessary that the Commanding Officer should be made acquainted with the intended manœuvres, in order that his movements may have a proper effect.

It should be remembered that horse artillery cannot be wheeled about on its own

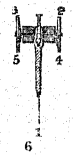
* From 'Regulations for the Exercise and Movements of the Royal Horse Artillery.'

† See Article "Evolutions of Artillery," in 1st volume of 'Aide-Mémoire.'

ground when acting with other troops: sufficient ground should be allowed on each flank to enable the subdivisions to wheel outwards, if required.

Horse artillery can readily be moved from one part of the line to another, but for purposes of review it should never be brought up into its position till all the troops are posted; for it sometimes happens that after the ground is occupied, the whole are ordered to move a few yards, or even a few feet, to a flank; or to dress back. Neither of these occasions much trouble to the infantry or cavalry; but it must be evident that to move a line of carriages a few yards to a flank, the whole must go to the rear, and each carriage make a considerable circuit, in order to come up square into its place: backing the carriages will rarely answer for any distance, when for the purpose of correct dressing.

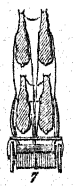
Although, strictly speaking, a troop of horse artillery has no right or left, but only acknowledges the front to which the guns and detachments are facing, yet, when a troop is reversed, the Commanding Officer, in ordering an advance or retreat from either flank, should make use of the word "*Present*" (*right or left*), which distinguishes it from the *proper*.



Should any difficulty of ground cause the natural order of the subdivisions to be inverted, their relative situations should be resumed at the earliest opportunity.

When the guns come into action at exercise, they should always direct their fire to a particular object, the distance of which should be named by the Commander, in order that the elevation may be regulated; or he will name the elevation.

In all manœuvres, as soon as the gun is limbered up, the detachment mounts and dresses on the subdivision of direction, on the word being given by the Nos. 1.



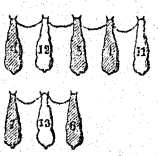
FORMATION OF A TROOP.

A troop of horse artillery usually consists of six pieces of ordnance: the men required for the service of each piece are—

For light ordnance. Eight mounted men, of whom two are non-commissioned Officers.

For medium. Ten mounted men, of whom two are ditto.

Heavier. Twelve mounted men, of whom two are ditto; with an addition of two men to each piece, mounted on the limbers, and numbered 2 and 3.



The mounted men are numbered off as follows, viz.—

With light ordnance { Front rank, 4 12* 5 1—Senior non-commissioned Officer.
Rear rank, 7 13* 6 11*—Junior ditto and marker.

With medium ordnance. { Front rank, 4 12* 5 10 1—Senior non-com. Officer.
Rear rank, 7 13* 6 14 11*—Junior ditto and marker.

With heavier ordnance. { Front rank, 4 12* 5 15 10* 1—Senior non-com. Officer.
Rear rank, 7 13* 6 16 11* 14—Junior ditto and marker.

* This mark denotes horse holders.



Each piece of ordnance is attended by an ammunition waggon, on the limber of which two men are mounted, numbered 8 and 9.

In this mode of telling off the men, they are numbered as

much as possible in conformity with the field batteries, so that there may be a unity of principle with all field ordnance.

The non-commissioned Officers and mounted men are called a detachment, which is placed in front, rear, or on a flank of their guns, according to circumstances.

No. 2 sponges, 3 loads, 4 serves the vent, 5 fires, 1 commands, 7 is in rear of the limber, 6 stands five yards in rear of the left wheel, and serves 3 with ammunition from 7.

When the number of men attached to a gun is reduced, 5, 6, 7, can best be spared, the gun continuing in action without them, by 3 going to the rear for ammunition, and 1 doing the duty of 5 in addition to his own. In action, Nos. 11, 12, 13 continue mounted in charge of horses; No. 11 leads his Officer's horse and that of No. 1 to the rear; No. 12 those of 4 and 5; and 13 those of 6 and 7.

When a detachment is reduced to six men, they are numbered

4 12* 1 } *12 and 11 being
7 11* 6 } horse holders.

Although ten yards is the distance nominally allowed the limbers in action, in rear of their guns, yet it is to be observed that when the nature of the ground is such as will in any degree cover them from the effect of the enemy's fire, a non-commissioned Officer is perfectly justified in taking advantage of it when the distance does not exceed a few yards either way.

In action, the whole are disposed of in the manner shown in the diagram (preceding page).

With respect to ammunition waggons, no positive rules can be laid down as to their disposition in action, which, on service, must in a great measure depend on a variety of circumstances: when it is practicable, they should be under the charge of an Officer, whose duty it will be to conform to the movements of the guns in such a manner and at such distance as to enable him to supply them with ammunition before that which is in the limbers can be expended. The spare carriages should be under the charge of the Quarter-Master Sergeant.

FORMATION OF A TROOP FOR INSPECTION.

Each troop forms in line with its guns, etc., in rear of their respective detachments, and in order to enable the rear rank to rein back for inspection, the leading drivers to be six horses' lengths from the rear rank: the inspection is then made according to order.

Distance of ranks. The distance of ranks is taken from the head of the rear horse to the tail of the front.

Close order. Half the length of a horse.

Order. Four horses' lengths, unless otherwise ordered

Distance of files. The distance of files is six inches from boot-top to boot-top. *Close files*—when the boot-tops touch without pressing.

Distance between guns. In line, the regular distance from gun to gun is, with four horses, 16 yds, and 3 yards additional for every additional pair of horses; consequently there will be the same distance between the right of detachments.

Distance of guns from their detachments.

In the rear.—Leading drivers one horse's length in rear of detachments, covering the centre.

On a flank.—A short horse's length from the flank of their detachments.

Guns. *In front.*—Detachments one horse's length in rear of their guns.

When a line breaks into column with detachments on a flank of their guns, it leaves an interval of two horses lengths' between the muzzle of each gun and the leading driver of the next.

OFFICERS, HOW POSTED.

2nd Captain. At open order, he should be on the right, and in line with the subalterns two horses' lengths;—at close order, and during manœuvre in line, between the two centre subdivisions, from which position he will be able to see the orders of the Commanding Officer properly executed, and be more ready to get to either flank for the purpose of dressing points. In column, he should be two horses' lengths from the centre on the reverse flank.

Subaltern Officers. The Commanding Officer places the Officers, one subaltern on the right of the troop, one on the left, and one on the right of the third subdivision (or of the fourth, if he means to name it the subdivision of direction).

Sergt.-Major. The Sergeant-Majors are to be in rear of the right gun of their respective troops two horses' lengths; when the waggons are attached, two horses' lengths in rear of the right waggon; in column, right in front, two horses' lengths on its reverse flank, dressing by the head of the column. When the left leads, and the Quarter-Master Sergeants are detached, they are to shift there, and keep on its reverse flank.

In changes of position in column they may be usefully employed in sometimes conducting pivots, and when a line is forming, in dressing or giving true points to their respective troops, in the given direction. It is their duty to see the limbers are properly disposed of when the guns are in action.

Quarter-Master Sergeant. The Quarter-Master Sergeants to be in the rear of the left gun of their respective troops (on the left) two horses' lengths; in column, on its reverse flank: they also assist it taking up points, etc., as well as the Sergeant-Major.

Trumpeters. The trumpeters on the right of the line, the left file two horses' lengths from its flank: when the movements are about to commence, they will join the respective troops, and be disposed of along the line, as the Commanding Officer may direct.

Artificers. The artificers in the rear of the whole, two horses' lengths behind the centre of their respective troops, and dressing to the same points as the line: they are considered detached in all situations of manœuvre.

A TROOP, HOW TOLD OFF.

The Commanding Officer, after numbering off the troop from the right by detachments, guns, and waggons, will tell it off into subdivisions, divisions, and half troops.

Throughout the service of artillery, six guns are generally termed a troop: for this reason it is the custom to tell horse artillery off as troops; two guns, with their detachments, constitute a division; one, a subdivision.

The waggons, although numbered with their guns, are not to be considered as part of the subdivision; but while they remain with them, they are to conform to every movement.

It may be sometimes necessary, in the march of columns, even to diminish the fronts of detachments; each detachment is therefore told off in *twos*.

Formation of several troops. When two or more troops are to act together, they are formed in line, and told off in the same same manner as for a single troop; the Captains are one horse's length in front of the centre of their respective commands, which commands will be allotted to them by the Commanding Officer; and when the reports are collected and made to him, he will number them by troops and half-troops from the right.

WHEELING.

Wheeling is a most essential operation, necessary in many changes of position, and in the formation of column and line.

When a troop is to wheel, a caution is given for that purpose, and to which hand. At the word "*March*," the front rank dresses by the Officer on the wheeling flank, who fixes his eyes and makes his circle on the standing flank man, and takes care that he does not exceed a moderate gallop.

The leader must take care to time his words "*Halt—Dress*" before the wheel is completed, otherwise an over-wheel and reining back will be the consequence. The whole halt, and dress by the standing flank.

The troop breaks into columns of any of the parts into which it is told off, by each of those parts wheeling up the quarter circle.

If the body is in motion, the wheels begin at the word "*Wheel;*" if halted, they are to begin at the word "*March.*"

In all wheelings, the conductors of the subdivisions look to the Officer or the non-commissioned Officer on the wheeling hand, and their subdivisions look to, and dress by them: at the words "*Halt—Dress,*" the whole are dressed to the standing flank, and remain so till a new direction is given, which will be—

'*Eyes* { *right*' / or '*left*' } to the pivot flank when necessary.

Distances in column are preserved from front rank to front rank.

When the line is to be formed by the wheeling up of its divisions, there must be no false intervals: the pivot man of the wheel turns his horse on his fore feet, keeps his ground, and comes gradually round with the rank.

Wheels of divisions of the line are made on a halted or a movable pivot; they are made from line into column, or from column into line, and also by the column of manœuvre or march, when moving on a considerable front, and when the wheel by which its direction is to be changed approaches to or exceeds the quarter circle.

When on a movable pivot, they are generally used, and ordered when the front of the column is small and its path winding and changeable. Although after the completion of the wheel in column or on a halted pivot, the pause made gives time, in large fronts, for exact dressing before the march is resumed, yet in small ones, where that pause is short, there is no time for such; attention to the preservation of the true distance being the material object. Whenever the wheel made is less than the quarter circle, the pause after the wheel will be considerable: should the wheel be greater than the quarter circle, it must be accelerated, otherwise more than one division will be arrived, and arrested at the wheeling point. Whatever is the front of the column, the words "*Halt—Dress*" are to be given just before the wheel is completed.

When wheels, or changes of direction of bodies in column, are made on a movable pivot, both flanks are kept in motion, the pivot one describing part of a circle, and the reverse flank, and intermediate men, by a compound of inclining and wheeling conforming to the pivot movements.

When the change is to be made to the pivot hand (the whole being in motion), the leader of the head of the column, when at the distance of twenty or thirty yards from the point of intersection of the old and new direction, will give the word—

'*Right*' / or '*left*' } '*shoulders forward;*'

which is a caution for each man to give a small turn of his horse towards the pivot hand; and the leader himself, carefully preserving the rate of march, without the least alteration of pace, will, in his own person, begin to circle into the new direction, so as to enter it 20 or 30 yards from the point of intersection. When this is effected (the rest of his division continuing to dress by him), he will give the word "*Forward,*" and pursue the straight line. The leader of the second, and every other division,

when he arrives at the ground on which the first began to wheel, will in the same manner follow his exact tract, always preserving his proper distance from him.

When the change is to be made to the reverse flank, the pivot leader having arrived, as before, at the spot, when he gives his word—

'*Right*' or '*left*' } '*shoulders forward*,'

for each man to give a small turn of his horse from the pivot hand, will begin, in his own person, to circle gradually into the new direction, so as to enter it 20 or 30 yards from the point of intersection of the two lines, when he will give the word '*Forward.*' During the change of either hand, the whole continue to look to the pivot flank, which never alters its former rate of march: in the one case the reverse flank is obliged to slacken, and in the other to quicken its movement. In this manner, without the constraint of formal wheels, a column, when not confined on its flanks, may be conducted in all kinds of winding and changeable directions; for if the changes be made gradual and circling, and pivot leaders preserve their proper path at the same uniform equal pace, the true distance of divisions will be preserved, which is the great regulating consideration on this occasion, and to which every other must give way.

Reversing. The command to reverse means that each gun and detachment is to go about on its own ground, the one quite independently of the other; it is therefore very rarely given, but when the detachments are in front or rear of their guns, the word '*Right*' or '*Left*,' prefixed to '*Reverse*,' denotes to which hand.

In putting subdivisions about by sound of bugle, the following rules are to be observed:—

With detachments either in front or rear, it means they are to reverse to their left; with detachments on the left, to wheel to the right about; and with detachments on the right, to wheel to the left about.

MARCHING IN LINE.

The line being supposed halted, and dressed for the purpose of advancing, the leader of the directing subdivisions instantly endeavours to remark two or more objects in his front which are exactly perpendicular to the direction of the line: on the word '*March*,' he is to move on those objects, taking particular care as he approaches them to take up others in the prolongation of the direction in which the line is moving.

It must be the particular care of conductors of subdivisions, during the advance, to retain their proper distances from each other.

Inclining. Inclining is a movement by which a line or any part of it is carried on in a parallel direction, at the same time that it is gaining ground to a flank; it is equivalent to the oblique march. '*Right*' or '*Left—incline.*' At the word '*Incline*,' each man turns his horse on his fore feet, to the hand to which he is to incline, and the whole look to that hand. At no time during the incline ought the former front of the line to be in the least degree altered; that whenever the word '*Forward*' is given, the line (by each man at the same instant turning his horse) may be in a direction perfectly parallel to the former front, and ready to dress, or move on by either flank or centre. It has been ascertained that the greatest angle at which cavalry can incline is 34°, but artillery (in consequence of the intervals between subdivisions) can, if necessary, incline to a much greater angle.

PACES.

The walk, trot, and gallop, are the three paces; and of each of these there are

different degrees of quickness: but it is essential to the perfect movement of the troops, that every horse shall move at the pace ordered. Different paces ought not to be suffered in a body moving at the same rate. The Cavalry Regulations (Sec. 15, 16) must be strictly adhered to.

All alterations of pace must be made by each separate body composing a line or column as nearly together as possible. Though in slow movements of the line or column, or on a march, the walk is the common pace, yet, in general, all changes of position should be made at the trot or the gallop, according to circumstances, beginning and ending gently, to avoid confusion in forming: the intermediate time of such movements may be conducted with rapidity, and much depends on the eye of the Officer, and in well-timing the words of command.

COMMANDS.

All commands must be given by Officers, in a firm, loud, and explicit manner; every Officer must therefore be accustomed to give such commands, even to the smallest bodies, at the full extent of his voice: by such bodies he must not only be heard, but by the leaders of others, who are dependent on his motions.

Nature of commands.

Commands of caution, being such as are preparatory to a movement, should be sufficiently full and explanatory. Commands of execution should be short, and avoiding unessential words.

Commands by respective leaders.

The Officer commanding gives and repeats all general commands, which are also quickly repeated by all the Officers and by the senior non-commissioned Officers of such divisions as have no Officer: it is only when troops are broken into parts, that there is no Officer attached to the subdivision, that the Nos. 1 give commands, and those are chiefly executory, as '*Halt—Dress*,' etc.: also the several words necessary for the wheels made in column of march by subdivisions;—the several words necessary when the subdivisions come up successively from column into line, and in general whenever the subdivisions are moving as distinct though dependent bodies;—but the wheeling from general column into line, or from line into general column, is made at the word '*March*,' repeated by the Officers and non-commissioned Officers commanding divisions only. The whole column or line is also put in motion according to the same rule; but all general words of command given by the Commanding Officer to the whole when in motion, should be instantly repeated, not only by the Officers and non-commissioned Officers commanding divisions, but also by the non-commissioned Officers commanding such divisions as have no Officers attached to them.

It is impossible to ascertain the words of command to be given in all cases; when such are not pointed out, they must depend on circumstances: if they are clear and expressive of what is to be done, they cannot be too short.

Quick repetition of command.

After the Commander has announced the orders, etc., particularly the words of execution, as '*March—Halt*,' etc., the repetition of them by every other individual concerned must not be strictly successive, but as much as possible at the same instant, to ensure that precision of movement which is so indispensable; and the larger the body, the more essentially does this circumstance operate.

MOVEMENTS.

Movements ought to be divided into distinct parts, and each executed by separate and explanatory words of command.

Alterations of position in considerable bodies must begin from a previous halt, however short, except giving a new direction to the heads of columns, or increasing or diminishing their front, which may be done while in motion. As the principle of moving, forming, and dressing upon given and determinate points, is just,—quick

changes of position of a considerable body, formed in line, attempted while on the move, and not proceeding from a previous halt (however short), will be false and defective; the effects of which, although not apparent in a single troop, would be very obvious in a line or column of any extent: a pause between any change of situation, so essentially necessary to movements of great bodies, should seldom be omitted in those of small ones.

Squareness of dressing, the exact perpendiculars of march, and the correct relative position of the whole, are thereby ascertained.

Such alterations of position, made from the halt, may, when necessary, succeed each other instantly; no time need be taken up in scrupulous dressing, that every one may be immediately apprised of the movement which is to follow.

In the movements of a single troop, and in the taking up a new position, it may not seem material whether a flank of it is placed a few yards to the one hand or the other, or whether the line formed on is exactly directed to any certain point; but when a troop makes a part of a more considerable body, if its formations are not correct, it will create general confusion, and give false directions and distances to those whose situations may be determined by it.

The necessity of every single troop being accustomed to make its changes of position and formations on determined points, is therefore obvious.

Every leader of a body moving on any front whatever, who means to conduct it in a straight line, must march upon two points which cover each other; if such points are not ascertained for him, he must instantly determine them for himself; and if no strong and marked objects present themselves in the direction, he can never fail, by casting his eyes along the ground, to find such small ones as will answer his purpose; and these he renews from time to time, as he approaches them. To march straight on one object only, with certainty, and without wavering, is not to be depended on.

MARKERS, IN FORMING LINE.

When a column is wheeled up into line, the front rank is dressed on the marker's horses' heads, so that the men of the front rank will of course be half a horse's length from the line of the horses' heads of the marking persons. The same rule is to be observed in all formations of line, as well as in the connecting of a line, when it is necessary to throw out markers for that purpose. With the guns in rear or on a flank, the Nos. 1 march on the markers; and with guns in front, the leading drivers are marched on them.

The markers for these formations (except for action) are not to quit their ground till all the necessary dressing is accomplished, and they are directed so to do by '*Eyes front*,' from the Commanding Officer.

MOVEMENT FROM A FLANK OR FLANKS.

If a line is ordered to move off from any part of it in a column or columns, the following rules will serve as an explanation for all cases that can occur. If a troop in line with detachments on the left of their guns, is ordered to advance from the right in a column of divisions, the Officers, having repeated the words of command, will immediately place themselves on what is to become the pivot flank of their respective divisions, by shifting along the front: on the word '*March*,' the whole move off at the pace ordered; the right division straight on; the remainder wheel to the right by subdivisions, and move on without any pause; and as soon as the second division covers the first, that is, when the third subdivision covers the first, and the fourth covers the second, it is wheeled to the left by subdivisions: the other divisions will be wheeled up in the same manner, as they cover in the new direction.

In retiring from the right flank, on the word '*March,*' the two right subdivisions wheel to the right about, and then move on; the other divisions follow, as already directed.

In retiring from the left, the two subdivisions on the left of the line wheel to the left about. In some cases however the above-mentioned method of retiring from a flank may be considered objectionable; for instance, if, after having retired from the right in this manner in a column of divisions, it becomes necessary to wheel into line to the left, the consequence would be, that after having wheeled into line, the order in which the divisions were originally told off would be inverted: the second subdivision would be on the right of the first; the fourth on the right of the third; and the sixth on the right of the fifth. Therefore, when the next formation is foreseen, and that it is such as will affect the original order of the subdivisions, according to the rule already explained, the Commanding Officer, when he wishes to retire from the right flank by divisions, will change the front of the right division by subdivisions wheeling inwards about; the remaining divisions wheel to the right, and follow the first division. The same principle is applicable to retiring from the left flank.

FORMATION OF LINE FROM COLUMNS.

It is a general rule, in all formations of line from open column, that the part of the column next to that which is to be formed on (in order to enable it to form perfectly square) shall make two square movements; the remainder, to avoid going over unnecessary ground, need only throw shoulders forward. From close column the whole must necessarily make two square movements.

These rules apply equally with columns of every front.

BREAKING AND FORMING.

A troop formed in line occupies 100 yards nearly, when it moves from a flank in a column of subdivisions (without ammunition waggons): with the detachments in front or rear of their guns, it occupies about a third more than it did in line; but if it moves from a flank in a column of subdivisions, with detachments on a flank of their guns, by divisions, or in a column of a larger front, the distance between the front and rear pivot Officers is less than the troop occupied in line, by the front of the column, whatever it is.

Leaders in column.

When a line is broken into parts for the purpose of movement, each of these parts has a leader, who, in column, if an Officer, is always to be on the pivot flank: these Officers cover each other in the given direction in which the column is to move; they are not to be covered by any one, and are answerable for preserving true distances. Should there not be a sufficient number of Officers for this purpose, their places are to remain vacant, and not to be occupied by the flank files, for such flank files are invariably to cover each other.

Commands given in breaking into column.

When from the halt, a line, by wheels to a flank, breaks into open column, the words of command are—'*Half troops, divisions,*' or '*subdivisions, to the right*' or '*left wheel—march.*' When the wheel is completed, the respective commanders of half troops, divisions, etc., give the words '*Halt—Dress*' (by the standing flank), and then '*Eyes right*' or '*left*' (by the pivot flank); after which the whole is put in motion by the word '*March,*' dressing, as already directed, for the column.

Pivot leaders in column of half troops.

In wheeling to a flank by half troops, if to the right, the Officer attached to the centre division shifts to the left of the third subdivision, in order to conduct the pivot of the leading half troop; and the Officer who was on the left, wheels up, and remains on the pivot flank of that half troop; the Officer who was on the right continues there: if to the left, the Officer attached to the centre will be on the right

of the fourth subdivision, the left Officer continuing where he was; and the Officer on the right continues there to conduct that half troop.

Pivot leaders in column of divisions.

In wheeling to a flank by divisions, if to the right, the Officer on the right shifts to the left of his division; the Officer next the centre to the left of his division, and the Officer on the left of the troop remains on the left of his division. If the divisions are to wheel to the left, the Officers who are not already there shift to the right of their divisions.

Pivot leaders in column of subdivisions.

In wheeling by subdivisions, if to the right, the Officers are to be on the left of the first, third, and sixth subdivisions; if to the left, on the right of the first, fourth, and sixth subdivisions.

NECESSARY EXTENT OF A COLUMN OF MARCH.

It is a general rule, seldom to be deviated from (when it can be avoided), that a troop when moving in a column ought not to occupy more ground than in line. In all wheels of a column to change its direction, with a larger front than subdivisions, on a fixed flank, the outward Officer, or non-commissioned Officer (when there is no Officer with the outward subdivisions), directs the wheels, the quickness of which must be at least double the rate of marching, or the wheeling point would not be cleared in time for each successive division. In changes made on a movable flank, the outward Officer or non-commissioned Officer also directs.

Halt of the line or column.

The whole line or column should always be so correctly dressed, that when the word '*Halt*,' is given, the whole shall halt together; but should at any time the difficulties of ground, or any other cause, have opened out the column, or thrown subdivisions out of the line, in such case the halt of such must be successive, that is, they will not be halted till they regain their proper situation.

Close column.

The general object of a considerable close column, is to form the line to the front in the quickest manner possible, to conceal numbers from the knowledge of the enemy, and to extend into whatever direction the circumstances of the moment may require, which, till it is nearly accomplished, cannot be obvious to them.

A close column of cavalry has generally a front of half squadrons, and when it is meant to deploy into line, it very frequently doubles its front into squadrons.

A close column of horse artillery will be composed of divisions, or of a greater front, according to circumstances. In close column it will be found sufficient to have distances of two horses' lengths from the rear of subdivisions to the front of covering subdivisions.

The changes of direction in a close column must always be made on a movable pivot, to enable its rear gradually to comply.

In deploying into line, the whole do so by making two square movements, viz., by wheeling twice. Cavalry deployments from close column are generally made at the head of the column.

MARCH IN LINE.

It requires the greatest attention to march well in line: the subdivisions dress by their respective leaders, who must be particularly careful in preserving their distances, and guard against closing on each other.

When any part of a line is interrupted by an obstacle, each subdivision, on approaching it, will throw shoulders forward, or wheel, if necessary, and continue its march in rear of the nearest subdivision which has not been so interrupted.

In proportion as the subdivisions pass such obstacles, and that the ground permits them to form in line again, they will move up into their proper places (where a void space has been preserved for them) by throwing shoulders forward.

INCREASING OR DIMINISHING THE FRONT OF A COLUMN OF MARCH.

A column should not occupy a greater extent of ground than what it takes to stand on in line: it therefore follows, that whatever changes are necessary, the column ought not to be lengthened out while it can be avoided. The front of a column may be increased or diminished, either in motion or when halted; in motion it is performed either successively as each part arrives at the spot where the head of the column performed the operation, or by all at the same moment: in both cases, the Commanding Officer, when he intends reducing or increasing the front, gives the caution, and the leaders the necessary commands, taking care that the regulating divisions, subdivisions, etc., never alter the pace at which the column was marching, but proceed as if they were totally unconnected with what the others were performing; the proper pivot is, however, always to be preserved, unless circumstances require that it should for the moment be dispensed with.

While the detachments are on a flank, a column of subdivisions does not cause any lengthening out: if it is still necessary to decrease the front of the column, the detachments may be ordered in front or rear of their guns: if more, by throwing out a file, one in front, the other in rear; it may be necessary to decrease it sometimes still further (when there is not room for three files abreast), by doubling the left files behind the right, the word of command for which is, '*Left twos, right double.*' Filing from a flank answers the same purpose.

If a column of subdivisions right in front, is in motion, and the Commanding Officer wishes to increase the front of the column in succession, the Officer at the head of the column, halting in his own person, orders to the reverse flank all the subdivisions that are in front of the subdivision which will become the pivot one; the subdivisions so sent to the reverse flank taking their intervals, dressing, and rate of march, from the pivot gun.

COUNTERMARCH.

In the movements of cavalry, the countermarch of lines and columns is sometimes necessary; in those of the horse artillery the former is seldom or never required; but the countermarch of the column is perfectly applicable, when it is desirable it shall face in the contrary direction, and preserve its line of pivots.

In the countermarch of a column right in front, the Commanding Officer will give the caution to countermarch to the right, on which the coverers of subdivisions will place themselves on the pivot flanks, in a line with the muzzle of the gun, but facing to the rear: on the word '*March,*' the whole move off together; the detachments, after having advanced five horses' lengths, are halted by their respective Officers or non-commissioned Officers; the guns continue moving on, and when they are sufficiently distant from their markers to allow them to be formed quite square in the opposite direction, both guns and detachments are wheeled to the right about, the latter on their centre; both receiving the words '*Halt—Dress,*' from their respective Commanders, or their coverers: the column will thus change its front and flanks.

Wheeling the detachments about answers the same purpose as filing, and is attended with less risk in the operation.

In the countermarch, the detachments and guns are invariably wheeled severally about, towards the flank which is not the pivot one.

ECHELON.

The echelon position and movements are applicable in many situations, and they are particularly adapted to resist attacks in front, and flank or flanks.

The oblique change in echelon is produced by the wheel less than the quarter circle of subdivisions; it is therefore practised when it is wished to move to the front or rear, and at the same time to gain ground to a flank.

The direct echelon is produced by the perpendicular and successive march of subdivisions to front or rear.

CHEQUERED RETREAT OF THE LINE.

The movements of a corps of cavalry retreating will be generally more or less accomplished by chequered movements.

Cavalry frequently retire by alternate squadrons or half-squadrons; no determinate rule can however be laid down for the movements of horse artillery attached to cavalry, in such cases, as they must very much depend on the nature of the country to be defended.

With cavalry, the line is told off by alternate right and left squadrons and half-squadrons; and of two that are contiguous, one for the direction of each line is announced. When it is the intention to retire, the right squadrons or half-squadrons are ordered to stand fast; the left go about by threes; the retiring part marches a certain distance, and when ordered, halts and fronts: this serves as a signal for the advanced part of the line to begin its retreat in the same manner, when each goes through its proper interval, and when ordered, halts and fronts: the alternate retreat is thus continued at the rate ordered, while found necessary.

As a general rule (subject to exceptions), the artillery will be on the flanks of regiments or brigades, according to circumstances, and told off right and left subdivisions, divisions, or half troops, in proportion to the number of guns; the right retiring with the right squadrons or half-squadrons, the left guns with the left, each unlimbering when halted, and firing when it can be done with effect.

In many situations, especially when a retreat is conducted with order, and slowly, it will be found that the retiring with the prolong has many advantages; by that method a constant fire may be kept up, and the frequent limbering and unlimbering (by which much time is lost) is avoided.

In a third method, where ground and other circumstances will admit, the whole of the guns may remain with the rear squadron, which will give confidence to the cavalry, and check the enemy in porportion.

MANŒUVRES OF FIELD BATTERIES.*—

Artillery of manœuvre constitutes the field artillery of an army. It consists in the British Service of the two divisions of Horse Artillery and Field Batteries: the former to accompany cavalry, the latter for infantry. The difference between these two is described in a few words. In the horse artillery the gunners who work the gun are carried, and accompany it on horseback. In the field batteries the same men are on foot, or they are carried on the carriages.

A troop of horse artillery and a field battery usually consists of six pieces of ordnance, viz. 4 guns and 2 howitzers. They are accompanied on Service by a considerable number of ammunition waggons and other carriages.

The carriage to which the gun is attached is called a limber, and carries a certain number of rounds, varying according to the calibre of the gun, ready for the most immediate service.

The ammunition waggon is also divided into two parts, called the waggon body

* By Colonel Fitzmayer, C.B., R.A.

and the waggon limber. They are attached to each other, and movable in the same manner as the gun and its limber. The main supply of ammunition is carried in these waggons: the waggon limber carrying the same number of rounds as the gun limber, and the waggon body twice as many as the limber.

The guns and their limbers form what is usually the manœuvring part of a troop or battery, and they are designated the first line of carriages.

The first 6 ammunition waggons constitute the 2nd line of carriages. They should conform their movements to their guns. On ordinary occasions of drill or exercise they always manœuvre with the guns of a field battery, and in rapid movements it is necessary they should do so, as the gunners can only keep up by being carried on them. The carriages remaining after these 6 can alone be considered spare. No troop of horse artillery or field battery could safely venture into a general action without having its second line of waggons tolerably near at hand. The supply of ammunition in a gun limber alone, especially with any calibre above a 6-pounder, being likely to become exhausted.

A field battery and a troop of horse artillery being precisely the same in every respect, all the manœuvres performed by the one can be in like manner performed by the other, and whatever applies to the movements of one applies equally to both. Either can manœuvre with or accompany cavalry or infantry, and both have been repeatedly called upon to do so.

The different mode of conveyance of the gunners makes some difference in the details for drill, but none in manœuvring.

A field battery requiring to manœuvre rapidly, like horse artillery, must be accompanied by its second line of carriages. In this state the risk of casualties would be increased beyond what it would be if this second line of carriages could be kept out of fire; but the possibility of running short of ammunition would be diminished. A troop of horse artillery can move with rapidity, having its guns only, but it exposes more matériel of horses and men to the fire of an enemy than a field battery, and, without its waggons, it is continually liable to a want of ammunition.

Ten yards is the distance nominally allowed in action for the limbers to be in rear of their guns. This distance cannot be materially increased without producing a slackness of fire and entailing great fatigue on the numbers employed in bringing up ammunition. It is nevertheless most desirable that cover for the ammunition waggons and limbers should be obtained in action if the nature of the ground will conveniently admit of it. It is very seldom that this cannot be done, at all events for the rear carriages. Every care should be taken to prevent their being exposed to fire, but they should not be too distant from the troop or battery in a prolonged action. The captain should always know where to find them, and their movements should conform with intelligence to those of the guns they belong to; spare wheels and other articles may frequently be required from them.

A troop and a battery are told off in precisely the same manner; and a gun and waggon constitute a subdivision in both, though for drill or exercise in the horse artillery the waggon is dispensed with. In the field batteries it never is, though it may be.

The wheelings of horse artillery and field batteries are conducted on the same principles, and whatever has already been said on the subject with regard to the one applies to the other.

Six non-commissioned Officers and men may work a light 6-pounder; but for any gun of higher calibre less than nine non-commissioned Officers and men cannot do it efficiently, except on very favourable ground. Of course in action, with numbers reduced by casualties, the best that could be done would have to be done.

PARADE AND INSPECTION.

When a battery is to turn out, and boot and saddle has been sounded, the Officer on duty, the non-commissioned Officers, drivers and horses turn out immediately; the gunners fall in by gun detachments, and are inspected and told off by the non-commissioned Officers. The Subaltern on duty marches the men and horses to the guns, forms the detachments in order of march, and horses in. He then inspects the battery, receiving a report from the non-commissioned officer of each subdivision.

The battery limbered up is told off by subdivisions, divisions, and half batteries.

1 gun and its waggon constitute a subdivision.
2 subdivisions „ a division.
3 subdivisions „ a half battery.

It is numbered from right to left by subdivisions. It is told off into 3 divisions. No. 1, the right. No. 2, the centre. No. 3, the left. Subdivisions Nos. 1, 3, and 5, are also distinguished as right subdivisions of divisions, and 2, 4, and 6, as left subdivisions of divisions. A gun of direction is also named.

The spare carriages, when with battery, are formed into a third, and if sufficiently numerous, into a fourth line.

POSTS AND DUTIES OF OFFICERS AND MOUNTED NON-COMMISSIONED OFFICERS AT EXERCISE.

Second Captain, *in line, limbered up*,—one horse's length in rear of the centre.

In column,—two horses' lengths from centre of reverse flank.

In action,—he assists Captain in general superintendence. He dresses all points of formation, gives the word *steady* when they have been correctly taken up, and the formation complete; when required, he commands a division. His duties generally are analogous to those of a major in a regiment of infantry.

Subalterns, *in line, limbered up*.—The senior on the right of the right division; the 2nd on the left of the left division; the junior on the right of the centre division.

In column of route,—on the pivot flanks of the respective divisions.

In column of divisions,—on the pivot flanks of their respective divisions.

In column of half batteries.—The Subaltern of the centre division on the pivot flank of the leading half battery; the others continue on the same flank of their subdivisions as when in line.

In action,—between the guns of their divisions, a little in rear.

Staff Sergeants, *in line, limbered up*.—The senior on the right of the marker of the right subdivision; the junior on the left of the marker of the left division.

In column of route,—one on the reverse flank of the leading gun; the other on the pivot flank of the rear carriage.

In column of divisions,—one between the guns of the leading, the other between the guns of the rear division.

In column of half batteries,—on the reverse flank of the waggons of each battery. They take up all points in changes of position.

Markers, *in line, limbered up*.—In line with the leaders of the waggons, and covering their officers.

In column of route,—with their leading waggons covering their Officers. Without waggons, covering their Officers, and in line with the centre horses of the gun.

In column of divisions and half batteries.—They cover their officers; without waggons, on the reverse flank of their division. They take up points with the staff sergeants, in changes of position.

Farriers and Artificers.—The farrier is generally attached to the forge; but when the battery is limbered up, he is in the centre, in rear of the 2nd Captain. The other artificers are told off in gun detachments when not mounted.

Trumpeters, *in line, limbered up.*—On the right of the battery, in line with it, one horse's length distant.

All this detail is only for drill or exercises on ordinary parade.

The manœuvres of a battery are executed by movements from line, column and action.

A battery in column should not present a smaller front than that of divisions, except for passing obstacles, parking and unparking, and route marching.

A battery or any number of batteries acting with other troops, should conform to their movements, and proceed to the positions allotted to them in the simplest and most expeditious manner. Artillery should however remain in rear of any intended alignment until the other troops are finally formed.

A battery has no fixed right or left, and only acknowledges the front to which the guns point when in action, or the detachments face when limbered up; but when a battery is inverted, the Commanding Officer, in ordering an advance or retreat, should make use of the word Present Right or Left.

All words of command should be given in a firm, loud, and explicit manner by the Commanding Officer, and repeated by Officers of divisions before they give the executive word. The bugle should be rarely used, and never when acting with other troops.

In wheeling, the pace must increase from the pivot to the wheeling flank. Wheels are made on a movable pivot, except in wheeling from column into line, which can be done on a fixed pivot.

A battery limbered up should always dress forward, and if too far advanced, it must reverse and come up to the alignment.

Columns of Artillery are composed of batteries (when there are two or more), half batteries, divisions, and columns of route. They are on precisely the same principles as columns of Infantry, and are manœuvred in the same manner.

INSPECTION OR REVIEW OF A SINGLE BATTERY.

The battery is formed in line, limbered up; the detachments in the order of march.

The waggons, at order, ten yards in rear of their guns.

The Officers, at order; the subalterns one horse's length in front of and in the centre of their divisions.

The 2nd Captain, on the right of the battery, in line with the Subalterns.

The Staff Sergeants, on the centre flanks of the waggons.

The markers move up into the places of their Officers.

The Commanding Officer, in the centre of the battery, one horse's length in front of the Subaltern.

FOR A BRIGADE OF BATTERIES.

The Commanding Officer, in the centre, two horses' lengths in front of the Captains of batteries.

The Adjutant, on the right of the line, in line with the Subalterns.

The Sergeant-Major, on the right, in line with the waggons.

The other Officers and non-commissioned Officers as before.

MANTLETS* are musket-proof coverings used to close the interior openings of embrasures in casemates or parapets, to protect the head of approaches carried on by sap, and occasionally to afford additional protection in rear of the last-placed gabions; they may also be employed to cover the approach of men against a stockade, gate, or barrier, for the purpose of placing a charge of powder to effect their demolition.

* By Major Robertson, R.E.

Method proposed by Captain Robertson Royal Engineers, for adapting the perch and hind wheels of a Pontoon Waggon, to carry a Mantlet to give cover in placing a charge of Gunpowder against a Stockade.

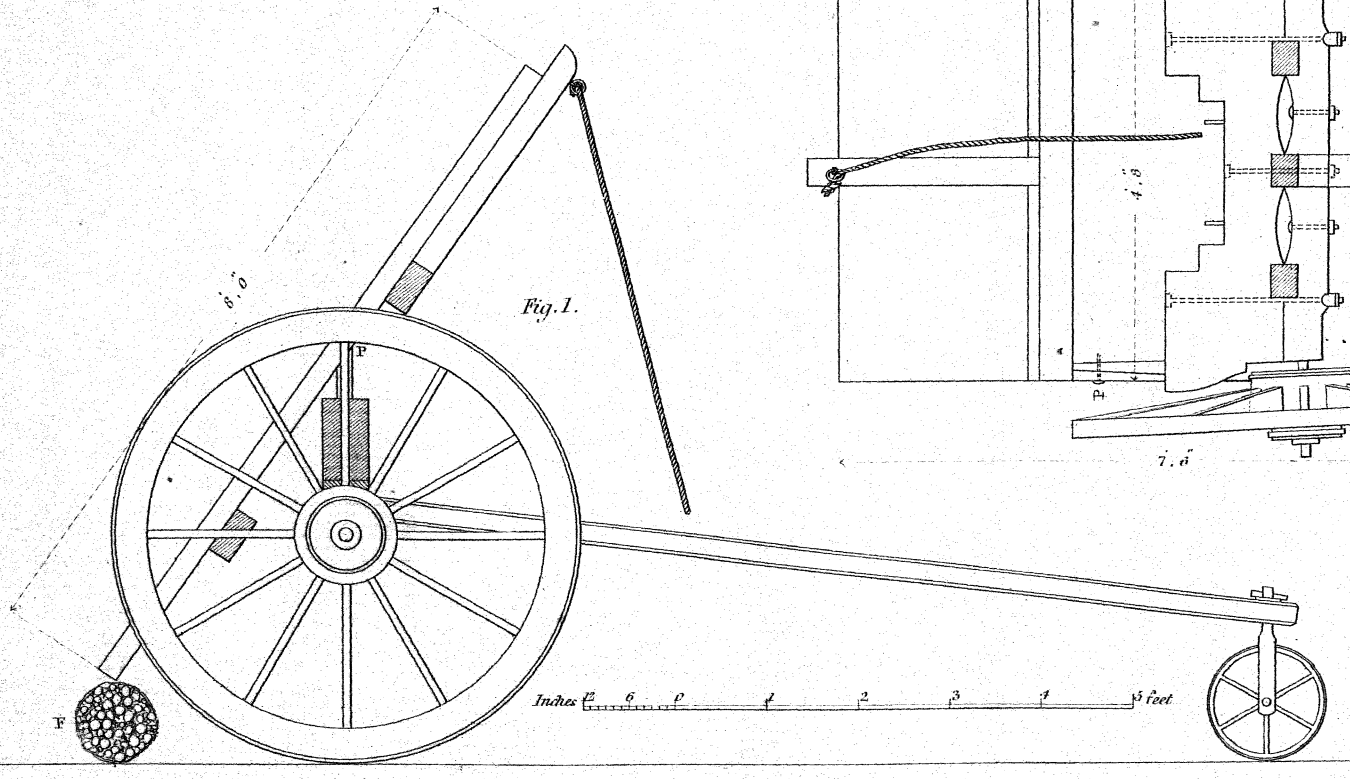
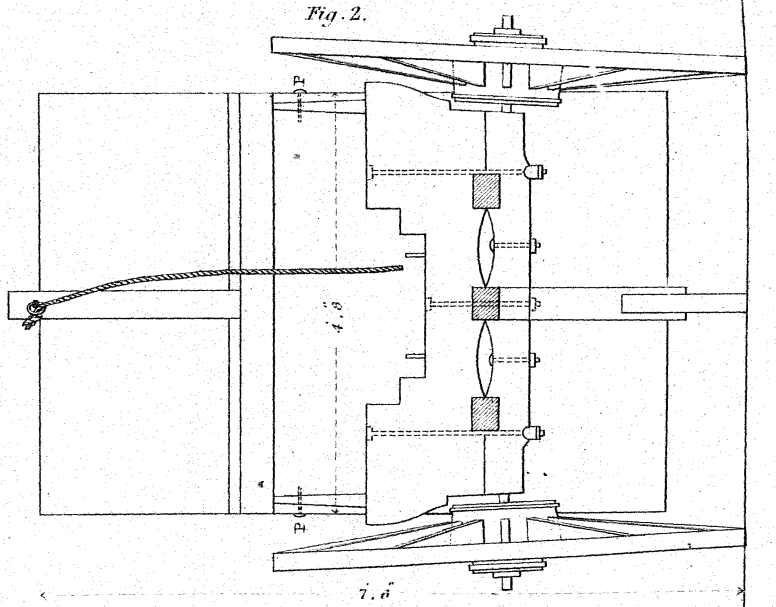


Fig. 1.

Fig. 2.



London: John Weale, 59 High Holborn. 1848.

T. W. Lowry, Sc.



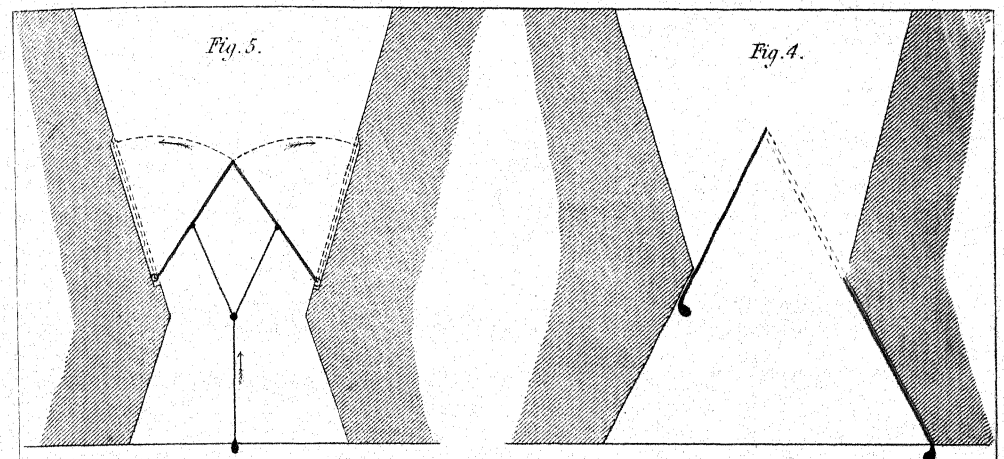


Fig. 5.

Fig. 4.

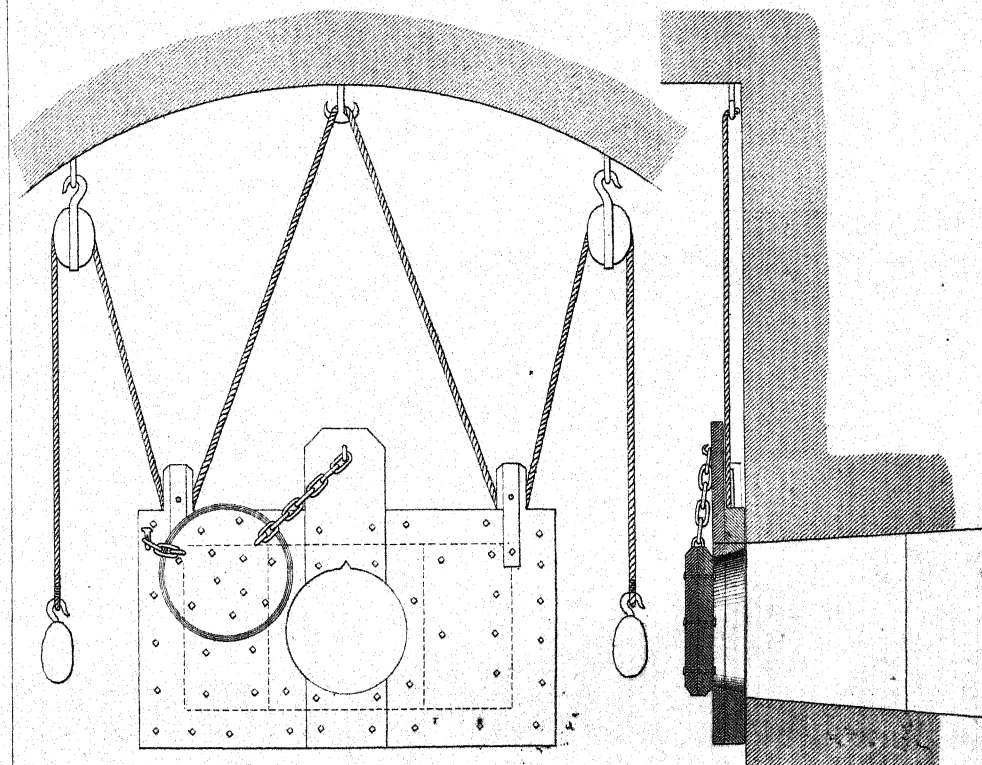
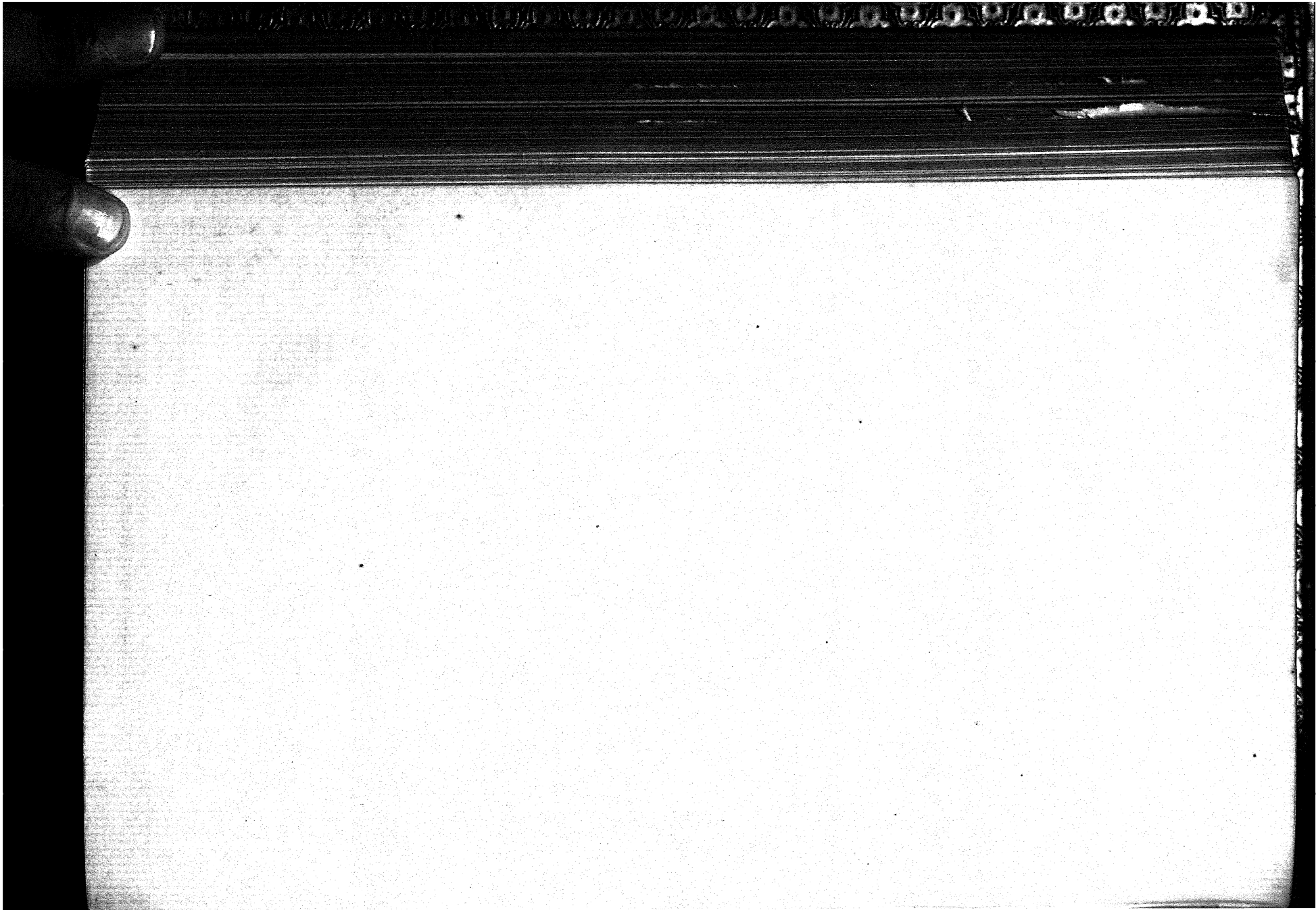


Fig. 3.



J.W. Lowry fc.

London John Weale, 59 High Holborn, 1848.



From experiments made by Lieutenant-Colonel M'Kerlie, R.E., at Chatham, it appears that the following materials afford musket-proof covering:

	Weight per foot super.
9-inch Baltic fir	28 lbs.
6-inch ditto with $\frac{1}{8}$-inch iron plate in rear	25
$3\frac{1}{2}$-inch sound oak	$16\frac{1}{2}$
$2\frac{1}{2}$-inch oak with $\frac{1}{8}$-inch iron plate in rear	$17\frac{1}{2}$
One thickness of 1-inch and one of 2-inch oak, placed equidistant $\frac{3}{4}$ inch from a $\frac{1}{12}$-inch iron plate between	$17\frac{1}{2}$
$\frac{3}{8}$-inch iron plate	15

$1\frac{1}{2}$-inch oak with a plate of $\frac{1}{8}$-inch iron in front, placed at an angle of 45° with the line of fire.

Musket-balls glance off a mantlet thus placed.

Plate I. Figs. 1 and 2 show a method of attaching a mantlet to the rear axle of a pontoon carriage, so as to afford cover in placing a charge of gunpowder against a stockade or barrier. A gun limber or cart wheels and axle might be similarly fitted for the purpose. P, P, are pivot-bolts, on which the mantlet turns, passing through holes in the wrought iron stanchions, which fit into the sockets in the bolster of the carriage.

The mantlet can be raised on arriving at the stockade, by means of the rope in rear, so as to allow of the powder being placed against it with security.

The powder should be placed on the perch.

Additional security may be obtained by nailing a couple of raw hides on each wheel; and a fascine may be hung, as at F, fig. 1, to cover the feet of the men working the mantlet.

Plate II. Fig. 3 shows the mode of hanging mantlets in casemates adopted by the Prussians.

Fig. 4, a form of mantlet applicable to embrasures, either in casemates or in parapets.

N.B.—In masonry embrasures, a mantlet might, it is conceived, be placed, consisting of two musket-proof shutters on hinges (*vide* fig. 5, Plate II.), which, when opened, would serve to protect the masonry of the cheeks of the embrasures from injury by the discharge of the gun.

LATER OBSERVATIONS.*

Experiments have lately been made by the Select Committee at Woolwich, on Rope Mantlets of various descriptions; and others proposed by Admiral Sir G. Sartorius, formed of hides with iron plates.

The results of the first ten experiments with rope mantlets gave data by which No. 11 was constructed, giving, on trial, protection at 50 yards, the penetration of the bullet varying from $2\frac{1}{4}$ to $4\frac{1}{2}$ inches, while the total thickness of the mantlet was 7 inches. The same amount of protection was obtained by two thicknesses of No. 6 hung together. No greater range than 300 yards was tried. The following table gives the results of the trials. The weapon used was the Enfield rifle. Ball 530 grains, charge $2\frac{1}{2}$ drachms.

Note by Compiler.—From the Table it appears that rope mantlets, though available as a last resource, especially on board ship or in a dockyard, are of so great weight as to be very unsuitable as an article of transport. They require great care in their construction, as otherwise the shot will pass through at the intersection of the ropes of the different layers.

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* Compiled by Captain Binney, R.E., from the Reports of the Select Committee, by permission of the Right Honourable the Secretary of State for the War Department.

Rope Mantlets.

Distinguishing Number.	DESCRIPTION.							Dimensions.	WEIGHT.				Remarks.
	Rope laid.		Yarn loosely laid up and plaited 3-strand as gasket.		Construction.		Note.		Total.			Per foot super.	
	Layers.	Size. Inches.	Layers.	Size. Inches.	Layers.	Plaited as gasket.		Super. feet.	Cwt.	qrs.	lbs.	lbs.	
1	3	4			vert.			29	4	1	26	17	No protection at 300 yds.
2	2	4½			,,			21	2	2	20	14	
3	2	5			,,			32	4	2	14	16	
4	3	5			,,			34	6	0	13	20	Cover at 100 yards.
5	2	6			,,			30	4	2	24	17	Cover at 200 yards, but not less.
6	2	7			,,			28	5	1	4	21	
7	1	3	1	5	horiz.	vert.	Plait on flat.	15	2	1	2	16	No protection at 300 yards.
8	1	2½	1	5	,,	,,	Do.	16	2	1	10	16	
9			2	5	,,	,,	Plait on edge.	16	2	1	24	17	
10			6	4½	2 ,,	*4 ,,	* { 2 inside. 2 outside. }	14	3	0	20	25	
11	5	4½			2 vert. 2 horiz. 1 vert.			16	3	3	21	27½	Protection at 50 yards.

HIDE MANTLETS.

The advantages claimed by Sir George Sartorius for these mantlets are, that they form—

1. A simple and portable defence for soldiers and sailors, embarked in boats, against the fire of small arms.

2. A simple, effective, and movable defence for vessels, gun-boats, and gun-rafts, when approaching within rifle range. As these mantlets can easily be shipped or unshipped, rolled up or laid flat, they form no real encumbrance.

3. Boats so protected and filled with riflemen would form a most important auxiliary to gun-boats and rafts closely engaged.

4. When heavy ships are engaging batteries at close quarters, the mantlet can be easily adapted to fall over the gun-port and protect the gunners from musketry or rifle fire; the same will apply to batteries within rifle range.

5. They can be used in the advanced trenches, etc., at sieges.

These mantlets are hung by the top, the remainder being left loose, so that they present a moving resistance greatly lessening the effect of the shot upon them.

The hides must be both thick and pliable, and are all the better for being fresh from the animal. They are useless against the rifle without steel plates, but with them are capable of giving great protection.

The plates are placed horizontally, of the same length as the width of the mantlet, and about 3 inches wide, which may be increased to 5 or 6 inches, without bad effect, but a greater width would cause difficulty in rolling up. Each plate is riveted by one edge to the hide, the other being free and overlapping the plate below it about ¼-inch. If the plates are laid edge to edge, a shot striking at the junction will drive them apart and pass though the hide.

The following Table gives the results of the experiments with the above mantlets:—

Distinguishing Number.	Thickness of Plates.	Method of attaching the Plates.	Dimensions.	Weight.			Per foot super. lbs.	Remarks.
				Cwt.	qrs.	lbs.		
1	$\frac{1}{16}$ inch.	Horizontal bars overlapping	2ft. 6in. by 2ft. 2in.		1	2	$5\frac{1}{2}$	Not shot-proof at 150 yards.
2	$\frac{1}{8}$,,	Do. edge to edge	2ft. 6in. by 2ft. 6in.		2	0	9*	Do.
3	$\frac{1}{4}$,,	Do. do.	2ft. 8in. by 2ft. 8in.		3	8	13*	Proof at 50 yds.
4	$\frac{3}{8}$,,	Do. overlapping	2ft. 6in. by 2ft. 8in.	1	0	21	20	Do. 25 yds.

* These would have been slightly heavier if the edges had overlapped.

Note by Compiler.—It appears thus that a hide and steel mantlet of about 13 lbs. per foot super, gives the same protection as a rope mantlet of $27\frac{1}{2}$ lbs., and the hide mantlet of 20 lbs. protects at half that range. The importance of this subject is brought very prominently before us by the late siege of Delhi, where, as far as can be judged by the published accounts, the brave Lieutenant Salkeld, of the Bengal Engineers, and his gallant sergeants, might have escaped uninjured, had they been furnished with mantlets arranged in a proper manner.

C. R. B.

MARINE ARTILLERY.*—The Royal Marine Artillery, formed by Order in Council, 18th August, 1804, consisted of three companies, to which a fourth was added in 1805.

The principal destination contemplated for the Marine Artillery, as recited in the Order in Council, appears to have been for service in bomb-vessels, and to instruct the other part of the corps of Royal Marines in the exercise of guns.

In 1806, the Marine Artillery completed at Land-Guard Fort, by extensive experiments, Tables of Ranges for 13 and 10-inch sea-service mortars, the use of which ordnance was especially assigned to this corps. Circumstances extended the services of the Marine Artillery, who were now, besides serving in bomb-vessels, mortar-boats, gun-boats, and rocket-boats, employed with heavy and field artillery in desultory debarkations, and other cases at sieges, and more permanently on shore.

A Professor of Mathematics was attached to the Marine Artillery, under whose instruction the Officers passed through a course similar to that at the time pursued at Woolwich. After the war, a Laboratory of Instruction was added, which indeed includes those usually denominated Repository Instruction, as well as those of the laboratory, essential to be known by artillerymen on service. At the termination of the war, the Marine Artillery was increased to eight companies. In 1832 they were reduced to two companies. Several augmentations subsequently took place; and in June, 1847, the Marine Artillery was increased to ten companies. At the present time (1857) the total number (including officers) is 2611.

The annexed Table will show the strength of the Marine Artillery at its formation; also the periods and amount of the principal reductions and augmentations it has undergone.

The Officers selected for the Marine Artillery companies are now educated at the Royal Naval College at Portsmouth.

* By Major-General Stevens, late of the Royal Marine Artillery.

It is probable that the great extension of steam navigation, which has in several respects indicated new wants, has influenced the increase of marine artillery; since, if furnished with strong detachments of marine artillery in each vessel, large numbers of merchant steamers, with seamen even untrained to artillery exercises, can quickly be converted into steam ships of war, on any sudden outbreak of hostilities.

The Royal Marine Artillery.

	Colonel 2nd Comm.	Lieutenant-Colonel.	Major.	Captains.	1st Lieutenants.	2nd Lieutenants.	Adjutants.	Quarter-Master.	Barrack-Master.	Surgeon.	Assistant-Surgeon.	Sergeant-Major.	Quart.-Mast.-Sergeant.	Barrack-Sergeant.	Sergeants.	Corporals.	Bombardiers.	Drummers.	Gunners.
First Establishment, Three Companies 18th August, 1804.				3	9	15									15	15	24	9	186
Four Companies, 2nd August, 1805.				4	12	20									32	20	32	12	248
Eight Companies, January, 1817.		1	1	8	16	16	1	1	1	1	1	1	1	1	48	32	48	16	480
Four Companies, 10th March, 1831.			1	4	5	8	1	1	1			1		1	20	20	12	12	316
Two Companies, 1832.				2	4	4						1			12	12	6	6	186
Ten Companies, 1847.		1		11	19	20	1					1			70	70	30	30	1250
Fourteen Comp., 1857.	1	2		15	37	18	1					1	1	1	154	126	84	42	2128

The pay of the Marine Artillery Companies is the same with that in corresponding ranks in the Royal Regiment of Artillery.

The duties of the Marine Artillery Companies are nowhere defined by any express order, except the Order in Council alluded to.

But they are expected and required to be acquainted with the service of every kind of artillery afloat.

Also to undertake the same on shore, whenever this extension of their duties may be deemed necessary for Her Majesty's Service.

In common with the other part of the Royal Marine Corps, their pay and accounts, when embarked, are entirely managed by the Paymaster and Purser of the ship in which they embark.

The head-quarters of the Royal Marine Artillery, at its formation, were with the head-quarters of the division of the Royal Marines at Chatham.

In 1819, their head-quarters were removed to Fort Monckton, near Gosport. In 1822, the Marine Artillery were sent, as a temporary measure, to the Upper Barracks at Chatham, in consequence of fever and ague having broken out to a great extent in the corps, attended by glandular affections, at Fort Monckton.

In 1824, the Marine Artillery moved to Portsmouth.

SERVICES.

The early services of the Marine Artillery, during the war, were in bomb-vessels, for which this corps was especially formed; but these were soon extended to gun, mortar, and rocket-boats; and by the natural exigencies of war, to the usual artillery duties on shore, in the field, in garrison, and at sieges. In 1805, they were employed

in bomb-vessels, chiefly under Sir Edward Owen, on the coast of France, in opposing the transit of the flotilla of invasion from one port to another—in bomb-vessels, at the passage of the Dardanelles, 1807—at the bombardment of Copenhagen, 1807—Bay of Rosas—at Basque Roads—bombardment of Flushing, 1809—in garrison, at the defence of Anholt—at Cadiz, during the long blockade or siege—at the defence of Tarifa, afloat—on the N. coast of Spain, under Sir Home Popham, 1811—in the Chesapeake, 1812—on the coast of Catalonia—on the island of South Beveland, with battery in the field—at New Orleans—in Canada, at sieges and attacks, as Fort Erie, Fort Oswego, etc.—at the bombardment of Algiers—on the N. coast of Spain, under Lord John Hay—in the Parana, and in numerous minor operations.

Note.—That the whole of the Royal Marine Artillery should be at Portsmouth when not afloat, now augmented to 1500 men, appears unnecessary, as this station is not adequate to the increasing wants of the Naval Service for that important force, essential to the perfect equipment of Her Majesty's fleets.

For the future extension and organization of the Royal Marine Artillery, there are two improvements desirable:—

First, to give every division its corps of Marine Artillery.

Secondly, to assign to the Royal Marine Artilleryman a position afloat correspondwith his importance and utility.

In respect to the *first proposition*, as the Marine Artillery is composed of men selected from the several divisions, and afterwards instructed in practical gunnery and laboratory duties, to qualify them to act afloat, much time would be saved in the subdivision of labour by having four stations instead of one; and each of the principal arsenals would always have the means of embarking their marine artillery, without sending to Portsmouth. This arrangement would likewise prevent any jealousy of the Portsmouth division having this Service attached to the division of Marines. The trifling additional expense in instructors is unimportant, compared to the advantages of facilitating the training and shortening the period of instruction.

The *second proposition*, rather startling by its novelty and apparent interference with the usages of the Naval Service, is merely, as expressed, to assign for the Royal Marine Artillery specific duties afloat, appropriate to the object of having them as a part of the equipment. The position of gunner or assistant-gunner is inapplicable to marine artillery, as those duties require men to be seamen, entrusted with the navigation of the vessel, and who are Officers and petty Officers, and take the responsibilities of command according to their rank.

It would seem necessary, to prevent confusion, to term the Royal Marine Artilleryman, when embarked on board Her Majesty's ships, *a bombardier*, and attach two or three bombardiers to every shell gun, of which every vessel has now a proportion equal to $\frac{1}{10}$th of her armament, and steam ships of war are chiefly armed with them.

Old sailors remark, that considerable danger exists in the introduction of shells afloat, particularly since the adoption of the concussion and percussion shells: this gives a force to the second proposition, of terming the Royal Marine Artillery, when embarked in ships of war, as *bombardiers*, and consequently of dropping that of *gunner*. It is true that seamen are instructed in practical gunnery, and are called naval gunners; but they are not permanently entered in the Service, and may not be always forthcoming when wanted: hence the importance of a large marine artillery well instructed in laboratory duties.—*Editors.*

MARINE ARTILLERY OF FRANCE.*

The artillery or ordnance for the French Navy and for coast batteries is all of iron, in distinction to that used in the field, which is cast in brass for all calibres. The ordnance, whether for the armament of ships or the defence of coasts, is termed Marine Artillery. The regulation of 1840 directed them to be of the following dimensions:—

8-inch, or 68-pounder } iron guns,
6-inch, or 30-pounder }
Howitzers 8-inch,
Mortars 12-inch,
} French measure.

The 30-pounder guns are divided into long and short; but a larger proportion of the old patterns remain in the French Service.

The *personnel* of the Marine Artillery of France has undergone several modifications from time to time: during the Empire it was employed in the field, and this corps distinguished itself at the battles of Bautzen and Lützen.

Latterly the Marine Artillery has been disconnected from the French Navy, arising out of disputes between the two Services,† and it has been organized for duties in the colonies under the Minister of Marine, which department has the administration of the French colonies.

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* From 'Le Dictionnaire de l'Armée de Terre.'

† In the British Navy this is not likely to occur, as there can be no rivalry when one corps is dependent upon the other; but there is a similar tendency to unite and possess all the attributes connected with the naval duties, now divided between the Admiralty and the War Departments; that is, that the Navy should supply itself, and manufacture its guns, stores, and ammunition, and eventually execute the garrison and other duties connected with the coast defences.

This tendency, which may be by some deemed imaginary, has nevertheless manifested itself in various ways in our Service, under the view of facilitating the supply to the Navy, and the improvement of those articles furnished and manufactured by the War Department; but the change, it is conceived, if effected, will neither lead to economy nor to improvement in the armament of Her Majesty's ships. An increased expense must of necessity follow the double establishments for the supply of guns, carriages, ammunition and stores, now furnished and manufactured by the War Department for the Army and Navy.

In respect to improvements likely to occur in the nature of the supply, we are inclined to believe that the ordeal of the Committee at Woolwich is an essential advantage to the efficient armament of ships of war.—*Editors.*

METEOROLOGY.*—The science of Meteorology embraces every thing connected with the atmosphere and its phenomena. The origin, force, and direction of the wind, the amount and times of the falls of rain, the changes of temperature and barometric pressure, all fall within the scope of this subject, and show how great is its importance in marking out the fitness of various parts of the earth's surface for supporting animal life, and encouraging the growth of the different vegetable productions. In order to collect data on which to found any practical rules for guidance, it is necessary that observations should be made during the same periods in many parts of the world. By collecting and carefully comparing such data, chiefly from the log-books of a large number of vessels, the late Sir Wm. Reid was enabled to publish his book on the Law of Storms, a work which has been the means of saving many valuable ships and lives, by teaching how to run *from*, instead of *into*, the vortex of those fearful rotary storms, or hurricanes, which so frequently occur.

In 1853, a conference was held at Brussels, to consider the best means of co-operating for the purpose of mutual benefit. At this meeting were present representatives from many of the Continental Powers, as well as Lieut. Maury, U. S. Astronomer, on the part of the United States of America, and Capt. Beechy, R.N., and Capt. (now Col.) James, R.E., on the part of the British Government. By carefully collating the logs of 10,000 ships, Lieut. Maury has constructed a series of wind and current-charts, which have already proved of the greatest value to navigators, the ocean being divided on the chart into spaces of 5° lat. and long., and the direction of the wind at any given time noted on each. By these means the routes to many places have been materially shortened; the course and effects of the gulf-stream more accurately determined; like currents in the Indian Ocean and elsewhere have been found; southwardly monsoons discovered on the west coast of Africa; the trade winds more defined; and the limits of the range of the sperm and other whales more fully ascertained.

The log used by co-operating vessels, gives the latitude and longitude of the vessel by observation and dead reckoning; the direction and rate of the wind; the height of the barometer and thermometer; form and direction of clouds; fog, rain, snow, hail, &c.; the state of the sea, its temperature, specific gravity, &c.

One great point to which attention has been drawn is the humidity of the atmosphere.

From observations made during balloon ascents, it appears that the cloud region, of which the temperature is nearly constant, varies in depth from 2500 to 5000 feet, at altitudes from 2000 to 7000 feet above the surface—light clouds, however, being found both above and below these altitudes—and the average decrease of temperature for altitude, without clouds, is about one degree per hundred yards.

One result of these observations refers to the theory of the diffusion of aqueous vapour in the atmosphere. It is commonly assumed that the vapour is diffused through dry air as if it were a vacuum, and that it consequently exerts a separate pressure depending on its quantity. This "elastic force" or "tension of vapour" has been supposed to diminish with the altitude; but observations, whether in balloons, or at the foot and top of mountains, seem to show that this tension is greater at higher elevations, and the vapour being less dense than air, it has the effect of diminishing the pressure of the atmosphere.

It has also been found that waves or systems of lines of equal barometric pressure have passed over very large portions of the globe at the same time.

These waves of barometric pressure have been observed to pass over large tracts of country and produce marked results, with reference to which Mr. Birt remarks, "In the case of a large wave stretching over an extensive area, the anterior and posterior trough would mark out parallel or nearly parallel lines of least pressure; the molecular

* Extracted, by permission, chiefly from Col. James's Report.

movement would be strongest in those troughs, and directed towards them from each side; at stations removed from them, the force of the wind would be greatly diminished, and at the intervening crest would be so small as to be scarcely appreciable, but, however small it might be, upon the crest passing any station, the direction of the wind at that station would be reversed, and it would increase in intensity until the transit of the posterior trough." The waves move from north to south at different velocities, from six to ten French leagues per hour in Asia and Central Europe, but much less in Russia; while in the Ural mountains the rate is sometimes less than two French leagues. Their rate also is much greater over the ocean than over mountain ranges, &c.; but there does not seem to be any connection between these waves and the direction of the wind.*

Professor Espy, from very numerous observations, arrived at many general results, some of which are the following, viz: That storms of rain and snow in the United States travel from west to east from November to March inclusive, and are accompanied by a depression of barometer near their central line, which is commonly of great length from north to south, and moves sideways towards the east at a rate of about 36 miles per hour, the wind for many miles on both sides of the minimum pressure line blowing towards it. On this line there is generally a lull or a calm, and when it passes towards east the wind generally changes soon to west, and the barometer rises. The fluctuations of the barometer are generally greater in the northern and eastern, than in the southern and western, parts of the United States, and when it falls suddenly in the west of New England it rises at the same time in the valley of the Mississippi, and at St. John's, Newfoundland. On the day preceding a storm the barometer is commonly high and the weather mild and clear. The temperature usually falls suddenly on the passage of great storms, so that the lowest temperature in the west often co-exists with the highest in the east. The queries to which these general laws give rise are as follows. Does the southern boundary of the winter storms reach the belt of high barometer on the north border of the trade-winds? and the northern boundary go into and beyond the belt of low barometer near the Arctic circle? Do these storms arrive in the Rocky Mountains and traverse the Atlantic with the phenomena above mentioned? Do they move towards a point south of east? The explanations are all given by the Professor in the following theory:

"When the air, in any locality, acquires a higher temperature, or a higher dew point than that of the surrounding regions, it is specifically lighter and will ascend: in ascending it comes under less pressure and expands; in expanding from diminished pressure, it grows colder about a degree and a quarter for every hundred yards of ascent; in cooling as low as the dew point (which it will do when it rises as many hundred yards as the dew point, at the time, is below the temperature of the air in degrees of Fahrenheit) it will begin to condense its vapour into cloud; and in condensing its vapour into water or cloud, it will evolve its latent caloric. This evolution of latent caloric will prevent the air from cooling so fast in its further ascent, as it did in ascending below the base of the cloud now forming; the current of air, however, will continue to ascend, and grow colder about half as much as it would do if it had no vapour in it to condense; and when it has risen high enough to have condensed, by the cold of expansion from diminished pressure, one hundredth of its weight in vapour; it will be about 48 degrees warmer than the surrounding air at the same height. This will therefore, without making any allowance for the higher dew point of the ascending current, be about one-tenth lighter than the surrounding colder air, and of course it will continue to ascend to the top of the atmosphere, spreading out in all directions above, as it ascends, and overlapping the air in all the surrounding regions in the vicinity of the storm. By thus increasing the weight of the air around, it will

* Admiral Fitzroy appears to demur to the above.—*Editor.*

cause the barometer to rise on the outside of the storm, and fall still more under the storm-cloud by the outspreading of air above, thus leaving less ponderable matter near the centre of the upmoving column to press on the barometer below.

"The barometer thus standing below the mean under the cloud in the central regions, and above the mean on the outside of the cloud, the air will blow on all sides from without inwards under the cloud. The air, on coming under the cloud, being subjected to less pressure, will ascend, and carry up the vapour it contains with it; as it ascends, it will become colder by expansion from constantly diminishing pressure, and will begin to condense its vapour into cloud at the height indicated before, and thus the process of cloud-forming will go on.

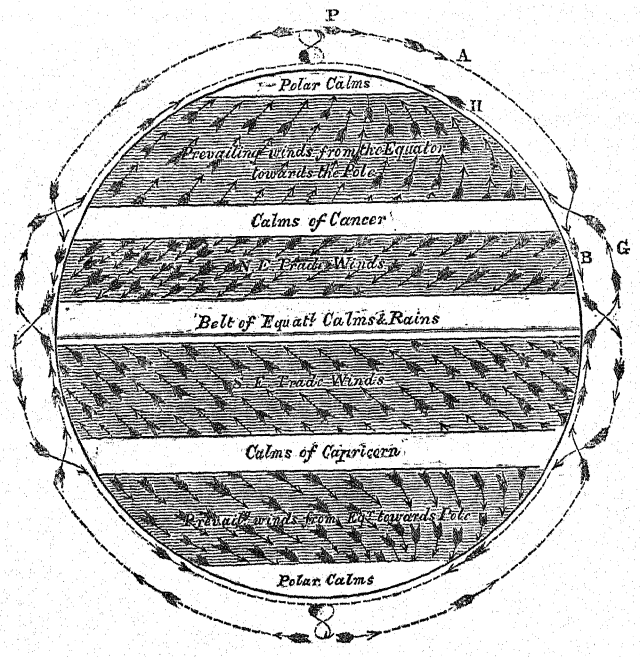
"Now, it is known that the upper current of air in the United States moves constantly, from a known cause, towards the eastward, probably a little to the south of east, and as the upmoving column containing the cloud is chiefly in this upper current of air, it follows that the storm-cloud must move in the same direction; and over whatever region the storm-cloud appears, to that region will the wind blow below: thus, the wind must set in with a storm from some eastern direction, and as the storm-cloud passes on, the wind must change to some western direction, and blow from that quarter till the end of the storm."

Lieut. Maury, U. S. astronomer at Washington, remarks that the atmosphere is a vast machine in magnificent order; a sewer which receives from every living breath a vast amount of dead animal matter; and a laboratory in which light and heat decompose the dead matter and develop gases which are again condensed into plants and trees. This condensation prevents the air becoming tainted and unfit for the respiration of men and other animals, and doubtless, when the animal and vegetable kingdoms lose their mutual counter-poise, severe typhoidal and other diseases ensue. The atmosphere also raises the moisture from the ocean, and carries it up to the high ground, whence it again descends in the channels of the rivers to the sea.

From the parallel of 30° north and south, nearly to the equator, we have the north-east trades on the north and south-east trades on the south; these constantly flow towards the equator, and therefore the air set in motion must return to the poles in some way to replenish the void. The return current moves in a direction opposite to the trade-winds, and must be in the upper regions of air, until it passes over those parallels between which the trade-winds are always blowing on the surface. These currents also apparently move in a sort of spiral curve, turning west from poles to equator, and east from equator to poles; this apparent motion is caused by the rotation of the earth from west to east on its axis, for if a particle of atmosphere, at rest at the North Pole, be set in motion direct for the equator, it would, as it travels south, find the earth slipping under it, and would appear to go from north-east to south-west, producing a north-east wind. In like manner, a particle going from the equator to the pole appears to be moving from south-west to north-east. The like operations are going on to the south of the equator.

These particles represent the aggregate of particles, or the currents, of air between the equator and pole. Now to trace the course of the wind, suppose the first particle starts from the polar regions, it travels in the upper atmosphere till it reaches the parallel of 30°, where it meets the other particle from the equator, and the two press against each other, producing a calm. Hence two under currents are ejected, viz. the north-east trades towards the equator and the south-west passage winds towards the pole; the trade wind continues till near the equator, when it meets the south-east trade, and another pressure and consequent calm region is produced. From the like cause also, rotatory storms originate on the confines of this tropical belt of calms, by means of the oblique passage of the trade winds into and along that region, just as little whirlpools are produced between the dead water and the current behind a rock; and they revolve in

like manner in opposite directions on either side of the belt. The particles here being pressed by surface winds rise upwards; and the one from the south now enters the northern hemisphere, travels till it meets, near the calm of Cancer, another particle from the north, then descends as before and proceeds towards the pole as a surface wind from south-west. As it enters the polar regions it is pressed upon by other currents, from every direction, and being whirled in a circular gale round the pole, it finally reaches the vortex and again ascends to the upper region, and starts afresh for the south. In the diagram, P represents the particle when it first rises at the north pole, it pursues the upper course A towards G over Cancer, descends as the north-east trade-wind B, then rises at the equator and passes south, while the southern particle passes north and follows the upper course G to Cancer, and again descends as H the south-west passage wind. As all these particles



thus enter the north polar region from the south-west, a whirl from right to left must be created at the north pole, and in the opposite direction at the south pole, and it has been noticed that all rotary storms revolve like the polar whirl of the hemisphere to which they belong. When the air of the equatorial calms is pressed upwards it expands and cools; a portion is condensed and comes down, producing such a heavy and constant rain that sailors profess to have taken up fresh water from the surface of the sea on those parts. The remaining moisture,—together with the vapour raised from other portions of the sea,—is carried over the land in regular quantities and by regular channels through the air, where it condenses and forms the sources of the great rivers of the earth, which are thus kept constantly replenished, and yet constantly roll their waters to the ocean. The remarkable fact is, that nearly all the large rivers are in the northern hemisphere, and the rain-fall in the north temperate zone is half as much again as in the south, while the ocean in the southern hemisphere is of much greater extent than in the north. From September to March, the sun, the communicator of motion to winds and waters, is pouring his rays on the seas of the southern hemisphere, and by means

of evaporation pumping up the water for our northern rivers. This being carried north, takes with it latent heat, a part of which is set free, and thus, at the approach of cloudy and falling weather, warms the atmosphere. It is well known that, in the northern hemisphere, as a rule, rain does not come with a north wind; because, in returning from the poles, the wind is generally in the upper regions of air, cut off from vapour, till it descends in the calm of Cancer and blows as a trade-wind. Here, like a dry sponge, it begins taking up and evaporating fresh water from the sea with great avidity, leaving the remainder, as would naturally be supposed, the saltest part of the ocean. When it reaches the equator it is full of moisture, and, proceeding on its way, refreshes the earth with rain and supplies the fountains of the rivers. On the other hand, the wind from the south-east trades travels in the upper regions to Cancer, where it descends and becomes the south-west surface wind; coming north it cools and begins to condense and descend in copious showers. Thus the large expanse of water in the southern ocean supplies the numerous rivers of the northern hemisphere, while the comparatively small surface of northern ocean—not more than two-thirds of the southern—feeds the few rivers of the southern hemisphere.

These calms and trade-wind belts move up and down every year about 1000 miles of latitude. In July and August the equatorial calm zone lies between 7° north and 12° north or higher; in March and April between 5° south and 2° north, always following the sun. In consequence of these changes, some places have a rainy and dry season, some are almost always rainy, others always dry, others have two wet and two dry seasons.

The mean annual fall of rain on the entire surface of the earth is estimated at 5 feet, which has to be evaporated from the ocean, carried from place to place, and precipitated in the right way by the atmosphere *i.e.*, this remarkable engine has to hoist to the clouds, and again lower to earth, the water of an enormous lake. In contemplating these results, and the perfect working of the whole machine, we may well wonder at, and adore, the amazing power and goodness of Him who hath ordered them all, and upholds them by the word of His power. It is also a remarkable fact that the more we understand the real state of natural phenomena, &c., the more we are struck with the clear declarations of the Scripture, as to the truth of views for a long time considered heretical. Thus the form of the world, the source from whence the rivers are supplied, the motion of the winds, the influence of the Pleiades, and many other points, too numerous to adduce, were all noted in the scriptures of truth long before the scientific mind had compassed their reality.

* The state of the weather, to use a familiar expression for one form of meteorology, depends upon the direction and force of the wind, the temperature and humidity of the air, the state of the clouds, the amount of rain, hail, or snow, which falls, and the lightning or thunder observed or heard.

Now all these ever varying phenomena of the heavens have their origin in two causes, viz. the position of the sun with reference to the different parts of the earth, and the rotation of the earth upon its axis.

Within the tropics, in those parts of the earth over which the sun is vertical, the temperature is greatest, and as we proceed north or south from the equator the temperature diminishes with the latitude; thus, in the Northern Hemisphere, the mean temperature of the air at the equator being . . . . . 81°·5

That at Jamaica is	78 ·8
New Orleans	67 ·0
Washington	54 ·9
Halifax	43 ·2

* By Col. James, Royal Engineers F.R.S., &c.

That at Fort Simpson	25 ·3
Melville Island	1 ·7

And in the Southern Hemisphere the mean temperature of the air at

Mararham, close to the equator, is	81°·4
At Rio Janeiro	74 ·2
Monte Video	66 ·8
Buenos Ayres	62 ·6
Falkland Island	47 ·1
Port Famine	39 ·0

In consequence of this unequal distribution of heat, the air expands and becomes lighter under the tropics, and rises into the higher regions of the atmosphere, where it overflows and is driven off towards the poles, whilst the colder air from the polar regions returns as an under current to restore the equilibrium.

But the equatorial regions and the atmosphere, as stated above, in consequence of the rotation of the earth, move with greater velocity than those parts which are at a distance from it; hence it follows that the atmosphere moving from the equatorial regions partakes of this motion as it proceeds towards the polar regions, and instead of proceeding directly north or south, proceeds obliquely in the direction of the earth's motion, that is, in a north-easterly or south-easterly direction, whilst the colder under current from the polar regions proceeding towards the equator is met by the higher velocity of that part of the earth, and becomes an easterly wind.

Thus on the Peak of Teneriffe the wind almost always blows from the westward, whilst the 'trade-wind' below is blowing from the eastward: the ashes from volcanoes within the tropics have been frequently found to have been carried hundreds of miles by the upper current of air, in a direction exactly opposite to that from which the wind blows in the lower regions.

Within 30° of the equator the under current of air proceeds steadily as an easterly wind, and has received the name of the 'Trade Wind:' vessels entering it carry it with them till they approach the line, where the northern and southern currents meet and produce the region of 'calms,' but subject to those violent rotatory storms which have been so ably described by the late Major-General Sir William Reid, and which have their origin in the meeting of the currents of air moving in opposite directions. The whirlpool and whirlwind are but the effect of eddies in the stream.

Beyond the latitude of 30°, the upper currents approach the surface of the earth, and dispute the passage, so to speak, with the colder currents from the polar regions, and thus it is that, in these latitudes, whilst the warm winds reach us from the south-west, we also experience the cold winds from the north-east, and that whilst the one is blowing in one part of very limited areas, the other is blowing in others; or if we watch the ascent of a balloon, we may not unfrequently see it rise and proceed at first with the wind in one direction, and then enter a current of air in a different or perhaps exactly opposite direction, thus proving that the currents are proceeding above and around us in different directions,—the colder from the north, the warmer from the south.

Land winds and sea breezes are produced by the higher temperature which the land acquires during the day than the sea: hence as soon as the earth becomes heated, there is an ascending column of air from the land, to be supplied by the colder air from the sea. And if the temperature of the ground at night falls below that of the sea, the current is reversed and the land wind prevails.

The amount of *vapour* in the air, where there is a full supply of water, depends on its temperature: hence in warm climates, in those places where the prevalent wind is from the sea, the moisture of the air is excessive; and in all places where the wind blows from the sea, the humidity of the air is in proportion to the temperature; as

evaporation proceeds the vapour rises into the air, is borne up by the ascending currents, and carried into the higher regions of the atmosphere.*

If a stratum of air saturated with invisible vapour ascends into a colder region, the vapour is partially condensed and is seen in the form of clouds, and if these clouds meet with a still colder stratum of air, the vapour is further condensed and descends as rain; or, if the cold is sufficiently great, as hail or snow. From these considerations it would follow that the quantity of rain which falls at any place should be in proportion to the temperature of the air at that place; and as a general rule this is true, but the form of the land, and the prevalent direction of the wind at any place with reference to the sea or land, so alter the condition of the problem, that in many places we have the very opposite results,—thus in Chili rain never falls, whilst at Sparkling Tarn, in Cumberland, the quantity of rain which fell in 1848-9 was 148·59 inches, the average quantity which falls at the Royal Observatory at Greenwich being only 22·25 inches: but such apparent anomalies are readily explained; the clouds loaded with moisture are carried along till they meet with a mountain-range where the clouds are constrained to rise into a colder region, which immediately precipitates the moisture in the form of rain, and the air is robbed of its load. Thus, in the Andes, on the eastern side, moisture and rain are frequent, whilst in Chili no rain falls; in the Ghats, along the western coast of the peninsula of India, during the south-west monsoon, the quantity of rain which falls at Mahabuleshwer is 254 inches, whilst not a drop falls in the Deccan behind the Ghats. On the southern side of the Himalayas there is constant rain and moisture, whilst not a drop falls in Thibet on the northern side. Lieut. Maury remarks that the south-east trade-winds strike the Atlantic on the African coast, they blow obliquely to the north-west across the ocean to Brazil; and being then heavily laden with vapour, deposit it as they cross the continent, supply the Rio de la Plate and Amazon, and proceed till they reach the Andes, where every drop of moisture is condensed out of them, and they pass onwards cool and dry, not receiving fresh vapour till they have crossed Peru and reached the Pacific.

It is needless to multiply examples; wherever high land intercepts the passage of the clouds from seaward, there the greatest amount of rain will fall, and the amount which falls on the windward side will always be greater than the amount which falls on the leeward side of the range.

The altitude at which clouds float in summer is greater than it is in winter, and they float at a greater height in warm climates than in cold.

The height at which the clouds float in India is about 4500 feet; the height at which they float in Cumberland is about 2000 feet: hence it is that at about these altitudes the greatest amount of rain falls; as we ascend higher or descend to a lower altitude, the quantity diminishes, as will be seen by reference to the following Table, which is taken from Mr. Miller's Paper on the quantity of rain which falls in the Lake district of Cumberland and Westmoreland, published in the 'Transactions of the Royal Society.'

	Altitude above the Level of the Sea.	
	Feet.	Inches.
The Valley	160	170·55
Stape Head	1290	185·74
Seatoller Common . . .	1334	180·23
Sparkling Tarn . . .	1900	207·91
Great Gable	2925	136·98
Sca Fell	3166	128·15

* Mr. Glaisher estimates the quantity of water which is annually converted into vapour at upwards of 60,000 cubic miles.

The following Table is from Lieut.-Col. Sykes's Paper on the Meteorology of India, in the 'Transactions of the Royal Society.'

Mean of Seven Stations at sea level			81·70 inches.
At 150 feet	Rutnaghery		114·55 ,,
,, 900	,,	Dapoole	134·96 ,,
,, 1740	,,	Kundalla	141·59 ,,
,, 4500	,,	Mahabuleshwer	254·05 ,,
,, 4560	,,	Uttray Mullay	268·21 ,,
,, 6100	,,	Rotergherry	81·71 ,,
,, 8640	,,	Dodalutta	101·24 ,,

Col. Sykes says, "The explanation of the prodigious fall of rain at a level of 4500 feet is simple and satisfactory. The chief stratum of aqueous vapour brought from the equator by the south-west monsoon is of a high temperature, and floats at a lower level than 4500 feet; indeed, I have looked over or upon the surface of the stratum at 2000 feet. It is dashed with considerable violence against the western mural faces of the Ghats, and is thrown up by these barriers in accumulated masses into a colder region than that in which it naturally floats: it is consequently rapidly condensed, and rain falls in floods."

In plains or in those parts of the country where the hills have but a small altitude, the quantity of rain which falls on the ground is greater than the quantity which falls at different altitudes above the ground; thus, at Greenwich the quantity which fell in the year 1844 was

On the ground	23·2 inches.
24 above the ground	22·2 ,,
50 above the ground	14·6 ,,

Corresponding results were obtained at Westminster Abbey, York Minster, Whitehaven, Calcutta, and Bombay. This may be explained by supposing the cold rain as it descends to condense the moisture of the air through which it passes: it is stated in the Abstract of the Observations taken at Greenwich in 1842, that "where the rain has been warm in respect to the temperature of the air at the time, no differences have existed in the quantities of rain collected at the different heights, and that when the temperature of the air has been greater than the temperature of the rain, a difference has always existed."

As a general rule, the amount of rain which falls at any place depends upon the mean temperature of the place, and the quantity which falls in summer is greater than the quantity which falls in winter; this is the case within the tropics: at Greenwich and Toronto, the relative quantity which falls in summer and autumn, to that which falls in winter and spring, is about 2 to 1, but on the confines of the trade-winds, its limits being dependent on the position of the sun to the north or south of the equator, this may be reversed; thus, at Madeira the south-westerly winds are prevalent in winter, whilst in summer the easterly trade-winds prevail: the quantity of rain which falls in winter is eighteen times greater than it is in summer.

In the flash of *Lightning* we see the electric spark disengaged by the sudden condensation of the air and precipitation of vapour; this is followed by the collapse of the clouds and the rushing in of the air to fill the void, the noise produced by which is *Thunder;* or the different currents of air being in opposite states of electricity may cause electrical discharges: thus the spark is seen to proceed from cloud to cloud, or

from the cloud to the earth, descending harmlessly by good conductors, or with fatal energy to the masts of ships or the spires of churches, &c. &c., where not so protected.

The height of the atmosphere is estimated at from 50 to 60 miles, though it may extend to a much greater height in a highly rarified form; but in consequence of its elasticity and the condensation of the lower portion by the pressure of the upper, three-fourths of its volume is within 6 miles of the surface of the earth.

The average pressure of the atmosphere at the sea level is $14\frac{7}{8}$ lbs. per square inch, or equivalent to a pressure of 30 inches of mercury; but in consequence of the different density of the air depending upon the temperature, and those great displacements caused by currents in the air, the pressure is found to vary from 28 inches of mercury to 31 inches,—the ordinary limits of the scales applied to the barometer.

If the air was of an uniform temperature over any given place, the pressure would diminish uniformly as we ascended; but in consequence of the decrease of temperature as we ascend, and the greater density produced by the cold, this regularity in the decrease of the pressure does not exist: hence, in determining altitudes by the barometer, it is necessary to take this element into the calculation.

In consequence of the expansion of the air by increase of temperature, it is found that the pressure of the atmosphere diminishes as the temperature increases; thus the pressure of the atmosphere in the tropics is less than it is in places remote from it—it is less in summer than in winter—it is also less at the warmest hour of the day than at the coldest—it is less also when warm winds prevail than when the colder blow: this may be considered as the general law for the pressure of the dry air, but as the air is generally loaded with moisture in proportion to the temperature, it is necessary to deduct from the observed height of the barometer the pressure which is due to the vapour of water mixed with the air.

HORARY AND DIURNAL OSCILLATION OF BAROMETER.

It is known that the barometer has a tendency to a certain regular oscillation, independent of marked changes in the weather. In latitudes below 64°, the mean barometric height is greatest about $9\frac{1}{2}$ to 10 A.M., and least about $3\frac{1}{2}$ to 4 P.M.; while above 64° it is reversed. A second maximum is commonly attained about 10 P.M., and a second minimum about 4 A.M.

Baron Humboldt says—"The hourly variation of the barometer, which under the tropics presents two maxima at 9 or $9\frac{1}{4}$ A.M. and $10\frac{1}{2}$ or $10\frac{3}{4}$ P.M., and two minima at 4 or $4\frac{1}{4}$ P.M. and at 4 A.M., which are nearly the hottest and coldest hours of the day, was long the object of my most careful daily and nightly observations." Similar results were obtained from the observations taken in the Deccan.

On the other hand, from observations made in the Sandwich Islands, on a mountain above 13,000 feet high, it appeared that the barometer had there only two fluctuations—a minimum early in the morning, and a maximum about 3 P.M.; and Col. Sabine, R.A., states, that "it has become known, that in the interior of great continents very distant from the ocean or from large bodies of water, from whence aqueous vapour may be derived, and where the air consequently is at all times extremely dry, the double maximum and minimum of the diurnal variation of the barometer either wholly or almost wholly disappears, and the variation consists in a single maximum or minimum which occur respectively nearly at the coldest and at the hottest hours of the day;" and that "if the elastic force of the vapour be observed by means of an hygrometer, with the same care that the barometer is observed, and if the respective pressures of the elastic forces of the air and the vapours upon the mercury of the barometer be separated from each other, the diurnal variation of the

dry air exhibits at all stations in the temperate zone at which observations have hitherto been made, a similar course to that which the whole barometric pressure produces at the Russian station, where the air is naturally dry."

Professor Espy remarks on the horary variations of the barometer: "Besides the fluctuations of the barometer depending upon storms, there are four daily fluctuations produced entirely by the increasing and diminishing elasticity of the air due to increasing and diminishing temperature. When the sun rises, the air begins to expand by heat; this expansion of the air, especially of that near the surface of the earth, lifts the strata of air above, which produces a reaction, causing the barometer to rise; and the greatest rise of the barometer takes place when the increase of heat in the lower part of the atmosphere is most rapid—that is, about 9 or 10 A.M. The barometer from that time begins to fall; and at the moment of maximum heat, when the air is neither expanding nor contracting, the barometer indicates the exact weight of the atmosphere. The barometer, however, continues to descend, on account of the diminishing tension of the air, and consequent sinking upon itself, as the evening advances, and its greatest depression is at the moment of the most rapid acceleration of diminution of temperature, which is about 4 or 5 P.M. At this moment the barometer indicates a less pressure than the true weight of the atmosphere. The whole upper parts of the atmosphere have now acquired a momentum downwards, which, as the motion diminishes, causes the barometer to rise above the mean; this takes place at the moment when the diminution of the motion downwards is the most rapid. This maximum of rise, which takes place about 10 P.M., is small when compared with that at 9 or 10 A.M. As the barometer now stands above the mean, it must necessarily descend to a mean at the moment when the air is neither increasing nor diminishing in temperature, which is just before sunrise.

"If this be the true explanation of the four daily fluctuations of the barometer, it will follow that the morning rise ought to be greater at considerable elevations on mountains, provided they are not too great, because some of the air will be lifted above the place of observation by the expansion below. This deduction agrees well with the observations of Col. Sykes in India; he found the nocturnal falling minimum fluctuation from 10 or 11 P.M., to 4 or 5 A.M., to be ·0181 inch at Poonah, about 1800 or 2000 feet high, and the diurnal rising fluctuation from 4 or 5 A.M., to 9 or 10 A.M., to be ·0445 inch; and at the height of 4500 feet he gives these same fluctuations ·0240 and ·0636 inch; and at the height of 6407 feet, ·0433 and ·0490, as observed by Dr. Walker and M. Dalmahoy. At very great elevations it is probable that there would be only two fluctuations in a day—the maximum near the time of the greatest heat, and the minimum near the time of the greatest cold of the air. At moderate elevations, such as four or five thousand feet, the effect is to prolong the morning maximum at the upper station, so that it continues to rise there for some time after it has begun to descend at the lower station.

"The principle here assigned as a *vera causa* is too plain to admit of doubt. It is the mere application of the law that "action and re-action are equal and in opposite directions." It may, however, be illustrated in the following manner:—Let a person balance himself in a pair of large scales, in a stooping position, if he raises himself, his scale descends, and when he is erect, equilibrium is restored; in stooping down, his scale ascends as soon as his downward motion commences, and when his velocity downwards begins to diminish, his scale descends below equilibrium; and when he comes to rest, equilibrium is again restored: thus four oscillations of the scales will be produced by one upward and downward motion of his body, corresponding to one expansion and one contraction of the air in a day by heat and cold."

From careful observations made in the Mauritius it appears, that while the temperature gradually increases from a minimum between 4 and 5 o'clock A.M, to its

maximum between 1 and 2 P.M., and again gradually descends to its minimum, showing only one defined maximum and minimum; the barometric curve, on the contrary, shows two well-defined maxima and minima. Also that the first maximum of the barometer takes place while the temperature is increasing, and the second, when the temperature is decreasing.

Variation of Mean Height with Latitude.

M. Kaemtz gives the following as a result of observations made by Erman, Herschel, and others.

	Inches.
Mean height of barometer at sea level . . . . . =	29·974
At equator about . . . . . =	29·842
At latitude of 10° the pressure increases, and between 30° and 40° attains its maximum . . . . . =	29·999 or 30·076
From this zone it diminishes and about the 5th degree . . =	29·921
In more northern countries it descends to about . . =	29·763

Sir J. Herschel found the pressure increased from poles and equator towards about the 25th degree of latitude, the former increase being much more rapid than the latter. The isobarometric lines do not, however, follow parallels of latitude; for in equal latitudes the barometer is ·137 inch higher on the Atlantic Ocean than the Pacific.

The meteorological instruments employed in indicating the condition of the atmosphere will now be described.

Barometer.

The instrument employed to measure the pressure of the atmosphere is the barometer: the mode of constructing these instruments is very different, but the principle is the same in all.* If a glass tube about 3 feet long is filled with mercury and carefully inverted in a cup of the same fluid, it will be found that the mercury will stand in the tube, in consequence of the pressure of the atmosphere, at about the height of 30 inches above the surface of the mercury in the cup; or if a siphon, one end of which is closed, is filled with mercury, and then held in a vertical position so as to leave a vacuum at the closed end, the difference between the levels of the mercury in the two columns, as in the former case, will be about 30 inches, and vary in proportion to the pressure of the atmosphere.†

Fig. 1 represents the construction of the barometers which have been adopted for the use of the Officers of the Royal Engineers at our principal foreign stations. P is an ivory point which is the zero of the scale, and to which the surface of the mercury in the cup or cistern is exactly adjusted by means of the screw B, which raises or lowers the mercury as may be required; the brass tube surrounding the tube of mercury is the scale of the instrument, the upper portion of which is graduated so that with the vernier V the height of the column of mercury can be read to the one-thousandth part of an inch. The thermometer T is inserted at C into the mercury in the cistern, and the instrument is adjusted in a true vertical position by the screws at A. The corrections to be applied to the readings of the barometer are for capillarity, which is always additive, as the action of the tube is to depress the

* The Aneroid barometers are not referred to, for although they indicate any change in the amount of pressure, they do not accurately indicate the amount.

† Gay-Lussac's mountain barometers on this principle are very perfect instruments, and were used by the Officers employed on the Survey of the North American boundary.

height of the column of mercury: the amount of this correction is usually stated by the maker of the instrument, or is taken from Tables which give the amount for each sized tube. All the instruments sent to the Royal Engineer Stations have been compared with the standard barometer at Greenwich, and the index error of each determined. For strict comparison of the results obtained in different parts of the globe, it is necessary to reduce the readings to common standards of temperature, and to apply corrections for the altitude of the different stations above the level of the sea, and also for gravity, depending upon the latitude of the stations.

These corrections are rendered extremely simple by means of Tables which will be found in the Report of the Royal Society on Physics, and by the Tables computed from Bailey's formula for determining altitudes by means of the barometer; but it is only necessary to apply the correction for the index error and capillarity, and for temperature, to the periodical observations: the other corrections are applied only to the mean results.

Example.

Reading of Barometer = 29·756. Thermometer 77°.

Index error	+·009	
Capillarity	+·014	From Table.
Temperature	−·129	
	−·106	
Corrected	= 29·650	

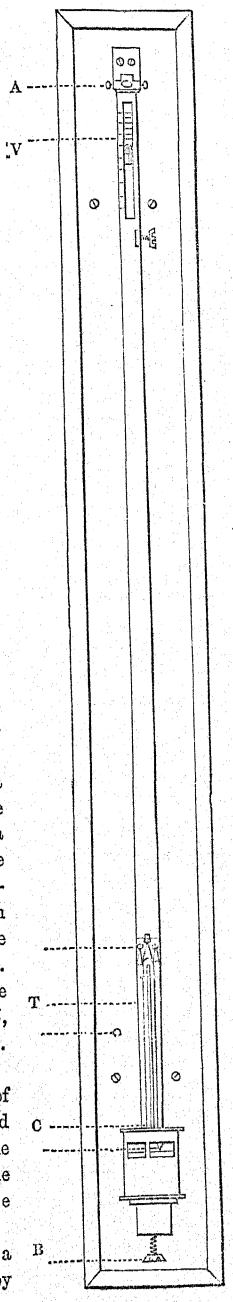
Instruments with closed cisterns, without zero points, require a correction for capacity, but these are not considered very accurate instruments.

It is unnecessary to describe the construction of a *Thermometer*, as every one is familiar with it. Seven have been sent to each of the Royal Engineer Stations; one is a standard thermometer about 20 inches long: these have been compared with the standard thermometer at Greenwich; the six others have been sent in a case, as shewn in fig. 2. No. 1 is for ascertaining the maximum temperature in the sun. No. 2, minimum temperature on the grass. No. 3, maximum temperature of the air. No. 4, the minimum temperature of the air in the shade. No. 5, the maximum indication of the wet-bulb thermometer. No. 6, the minimum indication of the same.

The maximum temperature is shewn by the position of the steel index in the tube of the thermometer; it is pushed along by the mercury, and remains at the highest point the mercury had reached: the small magnets M are for the purpose of moving the index, or holding it in the end of the tube when travelling.

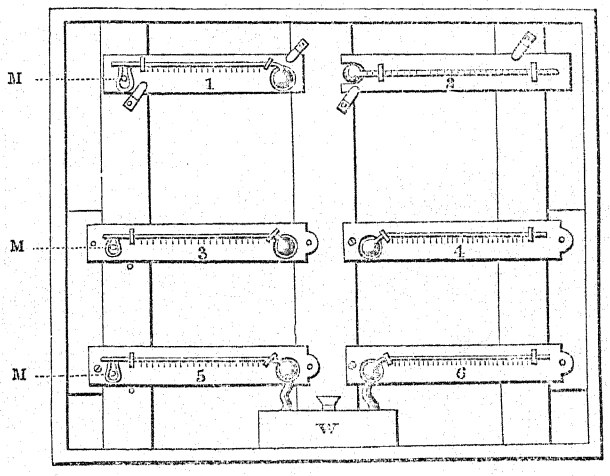
The minimum temperature is shewn by the position of a small porcelain index in the tube, which is carried back by

Fig. 1.



the spirit in the tube to the lowest point to which the spirit descended, where it remains; the spirit in ascending passes it without disturbing its position.

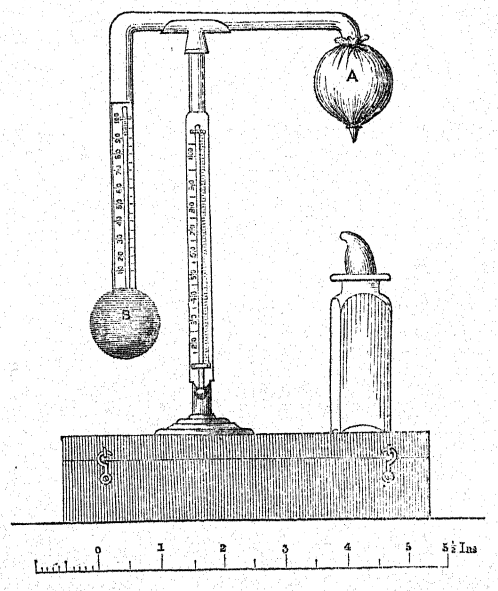
Fig. 2.



Hygrometer.

If we know the temperature of the air, and also the temperature of the dew point, *i. e.* to which the temperature of the air must be reduced to produce saturation or to precipitate the aqueous vapours contained in it, nearly all the hygrometrical problems can be solved. *Daniell's Hygrometer* is designed to indicate the temperature of the dew point; it consists of a tube bent as shewn in fig. 3, in one arm of which is a small thermometer partially immersed in the ether, with which the bulb B is half filled; the other bulb A is covered with muslin, and by dropping ether on it the temperature of the ether in B is rapidly reduced, till a ring of dew appears at the level of the ether in B: the exact reading of the thermometer at the moment the dew appears is to be noted, and is called 'the temperature of the dew point.' The temperature of the air is seen by the thermometer attached to the stand.

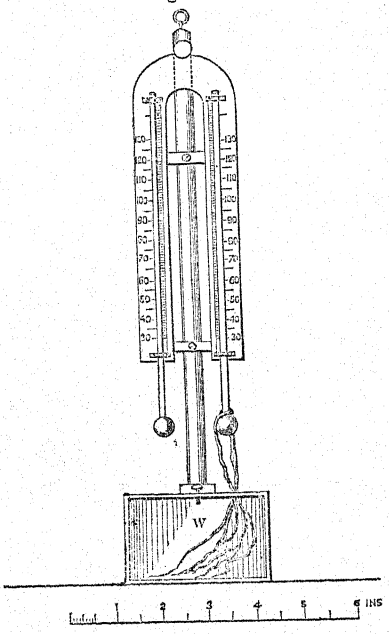
Fig. 3.



Wet and Dry Bulb Hygrometer.

This instrument consists of two thermometers: the bulb of one is covered with silk or muslin, and kept constantly moist by some threads of cotton or silk which are attached to it and communicate with a small vessel, w, of distilled or rain water; the other bulb is uncovered and exposed to the air. As evaporation proceeds from the wet bulb, the temperature is lowered in proportion to the dryness of the air: if the air is saturated with moisture, there will be no difference between the readings of the two thermometers; but if the air is very dry, the difference is very great, and has been observed as much as 20° in this country.

Fig. 4.



From simultaneous observations made at the Royal Observatory at Greenwich, with Daniell's hygrometer and the wet and dry bulb hygrometer, 'factors' have been obtained, which, if multiplied by the difference between the readings of the dry and wet bulb thermometers, and the product deducted from the reading of the dry bulb thermometer, give proximately the temperature of the dew point as observed by Daniell's hygrometer.

The 'factors' obtained from the Greenwich observations are given in the following Table, and an example of the mode of computing the temperature of the dew point is subjoined.

From the Greenwich 'Results,' 1849.	
Temperature of Air.	Factors.
20° to 23°	8·5
24	7·3
25	6·4
26 to 27	6·1
28	5·7
29	5·0
30	4·6
31	3·7
32	3·1
33	2·8
34 to 36	2·6
37 ,, 39	2·5
40 ,, 43	2·4
44 ,, 46	2·3
47 ,, 49	2·2
50 ,, 51	2·1
52 ,, 55	2·0
56 ,, 58	1·9
59 ,, 61	1·8
62 ,, 64	1·7
65 ,, 68	1·6
69 ,, 90	1·5

Dry bulb	66° · 5
Wet bulb	58 · 5
Difference =	8 · 0
Factor =	1 · 6
	12°. 8
Temperature of dew point =	53 · 7

Tables of the elastic force or tension of aqueous vapour have been calculated from experiments made by many distinguished scientific men; those of Dr. Anderson, from the experiments of Dalton and Ure, are considered by Dr. Apjohn as most correct. The Table in the Report of the Royal Society on Physics, &c., gives the height of the columns of mercury which the elastic force or pressure of the aqueous vapour mixed with the air is capable of supporting at every degree of temperature from 0 to 124° of Fahrenheit, and is a correction to be applied to the barometric heights, where the pressure of the dry air only is required to be known.

The temperature of the dew point, by the aid of that table, may be computed from the following formula by Dr. Apjohn:

$$f'' = f' - d\,(\cdot 0114) \times \frac{p - f'}{30},$$

where f'' = the force of aqueous vapour at the temperature of the dew point;
f' = " " " " of wet thermometer;
d = difference between the two thermometers;
p = pressure shown by the barometer at the time of observation.

The factor $\frac{p - f'}{30}$ may be omitted under the ordinary circumstances of temperature and pressure, but must not be omitted where observations are taken at considerable altitudes above the level of the sea.

In the example before given,

Temperature of the air = 66°·5
Wet bulb = 58 ·5 f' = 0·4880 tension of vapour from the Table.

8 ·0
·0114

·0912 — ·0912

Temperature of dew point 52°·5 = ·3968

The observed temperature of the dew point of Daniell's hygrometer was also 52°·5; the computed temperature of the dew point by Apjohn's formula is therefore correct, whilst there is an error of 1°·2 in the computation by the Greenwich factors; but it has been found that Apjohn's formula does not give correct results in places where the temperature, as in India, is very high, and the differences between the readings of the dry and wet bulb are as much as 35°. In some cases it is extremely difficult, if not impossible, to reduce the temperature of the ether in Daniell's hygrometer so as to produce dew on the bulb; and instruments by means of which a current of air is made to pass through the ether, by which the temperature is reduced several degrees below freezing, have been made,—of which that by Regnault is most approved. Hygrometrical Tables, with instructions for the use of the wet and dry bulb hygrometer, have been published by Mr. Glaisher, of the Royal Observatory of Greenwich, by the aid of which all the hygrometrical problems may be easily solved.

In the cases of instruments sent to the Royal Engineer Stations, Nos. 5 and 6 are wet bulb thermometers, and have a trough of water (w) below them. Nos. 3 and 5, or Nos. 4 and 6, are therefore dry and wet bulb hygrometers.

*Wind Gauge.**

The wind gauge is designed to measure the force and direction of the wind.

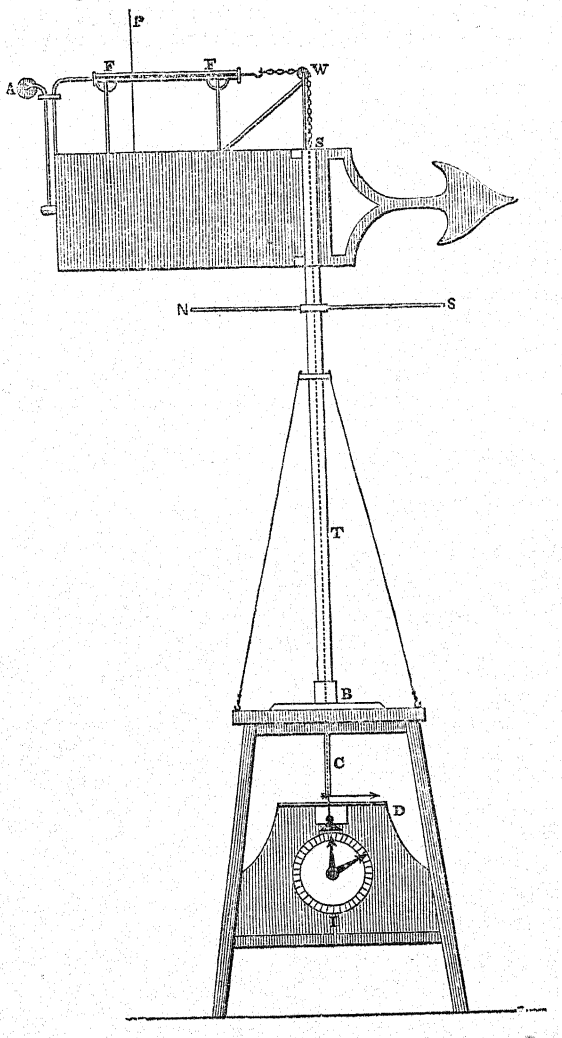
Lind's wind gauge consists of a glass siphon carried by a vane, one end of the

* See also ANEMOMETER.

siphon being bent, so as to point always in the direction of the wind: the difference between the level of the water in the two arms of the siphon indicates the pressure of the wind.

Whewell's wind gauge is on the principle of a wind-mill; it is kept directly facing the wind by means of the vane, and the pressure and velocity of the wind is ascer-

Fig. 5.—Wind Gauge. Scale $\frac{1}{16}$th the full size.



tained from the velocity with which the arms turn. But the most usual mode of measuring the pressure of the wind is to attach a square foot of sheet copper to a vane, the pressure on which is indicated by the compression of spiral springs, or by the weight raised by it. Fig. 5 represents the wind guages which have been sent to the

stations of the Royal Engineers; it is represented standing on a stool, to explain its construction, but it may be placed on the top of a house, and its indications read in any room of it, or it may be placed on a pole well steadied with guy-ropes, and its indications read at any convenient height from the ground.

It consists of a vane supported and turning on an iron tube T, and a plate of tin P, one foot square, sliding by means of a rod through it, on friction rollers in the upright supports on the vane: a wire is attached to the end of the rod, and is connected by means of a short piece of chain passing over the wheel (w) to another piece of wire leading to the index I, which is made on the principle of a common weighing machine; and as there is very little friction in any part, the pressure is very accurately seen by the index: the maximum pressure between the periods of observation is seen by means of a second hand which remains at the furthest point to which it has been carried by the index hand: a spur-wheel at A has been provided for each instrument, so that a piece of cord fastened to the other end of the rod may be led over it, and weights attached to determine the accuracy of the index: half the difference between the weights and the readings of the index may be considered the error of the instrument, and should be added to the index readings when the observations are recorded. The vane rests on a hollow truncated cone, on the end of the iron tube T, and there is a second tube C attached to the vane at S, which passes down through the tube T, and carries a hand or compass cord to indicate the direction of the wind: the inner tube may be lengthened to suit any room; the wire from the plate P of course passes down through this inner tube, and there are swivels placed on the wire to prevent torsion. The following Table of the relative velocity of the wind to the pressure upon a square foot has been calculated by Smeaton.

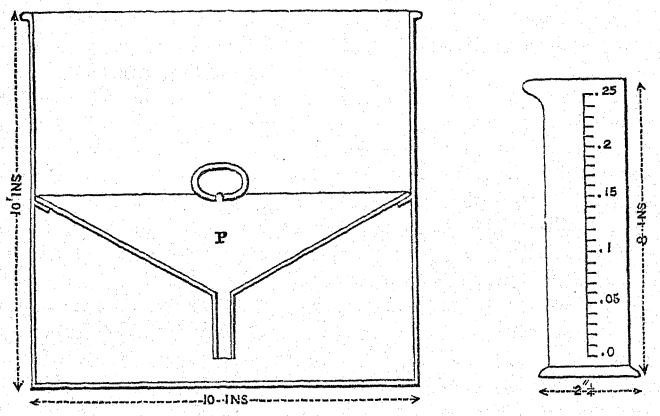
Pressure per square foot in lbs.	Velocity per hour in miles.	Appellation.
·005	1	Hardly perceptible.
·079	4	Gentle breeze.
·123	5	
·492	10	Pleasant brisk gale.
1·107	15	
1·968	20	Very brisk.
3·075	25	
4·429	30	High wind.
6·027	35	
7·873	40	Very high wind.
12·300	50	Storm.
17·715	60	Great storm.
31·490	80	Hurricane.
49·200	100	Violent hurricane.

Rain Gauge.

This instrument is for measuring the quantity of rain which falls at any place: the receiver is generally made with an area of 100 square inches, and the rain collected is measured in a graduated glass, so as to give the quantity in hundredths of inches; or a cylinder of sheet copper or tin, the area of the mouth of which is 100 square inches, and depth about 18 inches, has a conical bottom and a smaller cylinder 10 inches square in area soldered to it, in which there is a float carrying a scale: 10 inches of rise therefore in the scale indicate a fall of one inch of rain; a rise of one inch, a tenth of an inch of fall; and a rise of one-tenth, a fall of one-hundredth of an inch.

This is a very convenient form for a rain gauge ; but those which have been sent to the Royal Engineer stations are merely zinc boxes, 10 inches each way, with graduated glasses, as in fig. 6. The moveable partition (P) in the receiver, is to prevent loss

Fig. 6.



from evaporation ; the quantity received is poured into the glass measure, which, as it only measures a quarter of an inch if full, may have to be filled several times.

Indications of Change of Weather.

The words * Fair, Change, Rain, &c. &c., which are usually engraved upon common barometers at 29, 29·5, and 30 inches, &c. &c., on the scale, are so far correct, that if the mercury is rising or falling steadily to those points, such weather may confidently be expected, particularly if the hygrometer also indicates a decrease or increase of moisture in the air ; but a sudden fall of an inch in the barometer would almost certainly be followed by a storm, though the mercury might still be far from the level at which the word "Stormy" is usually written. So, again, we may have a continuance of fine weather, though the barometer never reaches the point for "Set Fair" weather. A gradual rise or fall indicates a change of weather which is likely to be of some duration ; whilst a sudden change in the barometer indicates a corresponding change in the weather. When the fall of the barometer is sudden, it indicates a vacuity over the spot, into which the air will rush to fill it, and this rush of the air will be in proportion to the fall of the barometer ; in great storms and hurricanes it has ranged upwards of three inches, that is, from 28 to upwards of 31 inches in height : this great height, when the storm is passing away, is due to the accumulation of air over the spot, after closing in from opposite sides. A falling barometer, when the dew point is high, indicates rain ; but if the dew point is low, it indicates wind without rain. The hygrometer should always be observed in conjunction with the barometer ; its indications are very important aids in prognosticating a change of weather, and the nature of the change.

* At great altitudes these words have no meaning whatever,—they would be above the extreme range of the mercury.

MINING, ARTILLERY.

PART I.—INTRODUCTORY REMARKS.*

In the 'Attack and Defence of Fortresses,' in this work, the subject of Military Mines was very briefly alluded to. This branch of Fortification is, however, to the Military Engineer, of paramount importance.

By a study of the 'Attack of Fortresses' it will have been seen how irresistible is its march; that the means of destruction at the disposal of the besieger, and the mode of application, render the reduction of a fortress a matter of calculation. The advantages of position, number, and material, are all on the side of the besieger. But so soon as the latter is compelled to engage in subterranean warfare, these advantages cease, or rather are transferred to the besieged. It is a very remarkable change. The French authors, Gumpertz and Lebrun, speaking of the difficulties which a besieger would experience should he attempt to carry on his approaches on a glacis defended by countermines, without in the first instance destroying them, say—

"The loss of a great number of men, and the discouragement of the whole besieging force, perhaps even their defection, would inevitably follow such a resolution. When, therefore, the front of attack is countermined, the besieger must call the miners of his army to his aid. This corps,—stimulated by the importance of the services they are called upon to perform,—proud that the progress of the attack is committed to their charge,—convinced that, although their operations are concealed from the eyes of their comrades, yet their daring deeds are not the less appreciated by them,—actuated by all these motives, penetrate below the surface of the earth, armed with thunder, to seek their enemy, to struggle with him in darkness, and finally to triumph over him;—their victory being incontestably the fruit of true courage,—of skill united to valour." And further—

"The miners of the besieged have, also, an equal claim to glory: although finally compelled to yield the victory to their opponents, it is an animating spectacle for the besieged to witness, that, by their art, the hitherto imperious march of the attack is for a time averted: so soon as it is known to the besieger that the ground over which his attack must pass is mined, his operations become, as it were, paralysed. The mine produces an effect in the ranks of the besieger far greater than the fire from the ramparts. The imagination exaggerates the danger, ever appearing more formidable as it is mysterious and obscure. It is in vain that the bravest of the besiegers attempt to push on the attack and overcome at all price the obstacle which impedes their advance. Yet a handful of men, by a slow, dangerous, and most difficult process, conquer, where numbers and courage succumb,—a striking example of the superiority of industry and skill over force. And now a struggle is commenced and carried on amidst silence and darkness. The besieged, who cannot avail himself of such large charges as are fired by the besieger, still retains on his side all the advantages of that science which foresees, observes, calculates, and regulates everything. His attentive ear is directed to all the points by which the besieger can advance. If the latter is heard, he is lost: a volcano whose existence he suspected, but whose destructive effects he could not escape, shatters his galleries, and buries him amidst its ruins; and yet no outward sign betrays to his companions the misfortune which has befallen him. The besieger then is satisfied if he can manifest himself by any effort whatever, and amassing hurriedly a quantity of powder, explodes it in the hope of narrowing the circle of operation of the mine of the besieged, while he

* By the late Lieut.-Col. J. Williams, R.E.

establishes a lodgement on the edge of the crater he has produced. But the besieged does not leave this newly acquired position long undisturbed, and by a mine which can be fired with sure and certain effect, overthrows his gabions and destroys the lodgement. Such is the début of a subterranean warfare: its continuation and its close are but a repetition of the same process. On the side of the besieger there are precaution and perseverance; on that of the besieged, care and activity; in both, patience and courage. The last scene in the combat shows the besieged repulsed but not conquered; while he may fairly proclaim that, for the continuation of the struggle, it is not courage that is wanted, but arms."

There can be no doubt that all Engineers, who wish to restore the balance between the attack and defence, should direct their attention to subterranean defensive operations; for a successful application of these may cause either the raising of a siege or a very considerable prolongation of its duration, and the time thus gained is often invaluable.

Military mining as a system has, however, hitherto played a secondary part in the operations of war. The only records of its extensive employment are to be found in the accounts of the siege of Candia by the Turks, in 1669, Schweidnitz, in 1759, by Frederick the Great, of Silistria in 1854, and Sebastopol in 1855. Notwithstanding, however, this disuse of mines in actual warfare, the subject has received considerable attention at different periods from distinguished Engineers; and systems (as they are termed) of countermines are consequently very numerous. Among the most celebrated of these systems are those of Goulon, Vallière, Mesgrigny, Delorme, Cormontaigne, Rugi, Mouzé, Dubuat, and Marescot. The object of the Engineer, in each system, appears to have been so to dispose his subterranean works as to destroy the various surface approaches of the besieger when in advance of his third parallel; but more particularly the breaching batteries which he established on the crest of the glacis.

A brief notice of the various circumstances under which, at different periods, mines have been employed in war, will properly preface the present article. Their earliest application appears to have been made in the *Attack*, and simply for the purpose of gaining access into the interior of fortified towns by means of a subterranean gallery passing under the walls of the fortress. The obvious inconveniences attending such a mode of attack soon occasioned its disuse, but a more successful employment of mining followed; viz. continuing the galleries only as far as the foundation of the principal wall, and then excavating the ground for a certain breadth (say about 100 feet) under its base,—the masonry being temporarily supported by wooden props, which were set fire to when the arrangements were ready for the assault,—so that the wall, being left without support, necessarily fell, and opened a breach to the besieger.

The introduction of mines in the *Defence* naturally followed their employment in the *Attack*. The earliest subterranean defensive position consisted of a gallery placed in advance of the foot of the wall, and termed an envelope gallery. From this gallery the garrison pushed forward small branches or galleries for the purpose of being warned of the approach of the enemy, and by these means to prepare themselves to resist his attack. The defenders occasionally employed these subterranean defences for overthrowing the towers, battering-rams, and other offensive weapons of the besieger. It may be remarked here, that from the circumstance of mines having been introduced in the Defence for the purpose of counteracting those employed in the Attack, the term *countermine* was given to defensive mines by the Engineers of that time; and the name, although apt to mislead, is still retained: some writers, however, apply the terms 'offensive and defensive mines;' and these latter designations appear the most appropriate.

Such was the nature of subterranean warfare previously to the invention of gun-

powder ; and, what is remarkable, almost two centuries elapsed between its invention and the use of it in mines. The circumstance under which the first mine charged with powder was exploded is thus narrated by Bousmard.

"The French, under Charles the Eighth, in 1503, having overrun with great rapidity the kingdom of Naples, were as quickly dispossessed of their conquest by the Spaniards, under the famous Gonsalvo di Cordova, surnamed the Great Captain. A single post, defended both by nature and art, alone remained in possession of the French, and resisted for three years the united efforts of the Spanish and Neapolitan armies to reduce it : this was the Castello del' Uovo, in the bay of Naples, constructed on a rock surrounded on all sides by the sea, except where a narrow isthmus formed a connection with the main land ; across the isthmus, however, a deep ditch or *coupure* cut in the rock, prevented all access into the interior. The natural defensive advantages of the position account for the length of the defence. The ingenuity of a Spanish Captain, Pedro Navarro, gave at length the victory to his countrymen. He took advantage of the contour of the rock to open, unseen from the castle, a gallery which he contrived gradually to drive forward till it had arrived under the castle ; and then placing a quantity of powder, he ignited it by a proçess which allowed the miner who applied the quick-match time to escape. The explosion caused a violent commotion of the rock ; great masses of it, together with a portion of the walls of the castle and a large proportion of the garrison, were precipitated amidst flame and smoke into the sea. Then the élite of the Spanish and Neapolitan armies landed from boats, and easily carried the breach made by the mine, but weakly defended by a small number of the garrison, already dispirited by the consternation produced by the explosion." Such was the success of the first experiment in mines charged with powder.

It appears that the success which attended this mode of destroying defensive works soon caused its very general employment : at the close of the fifteenth and at the commencement of the sixteenth centuries access into fortresses was very generally made by mines ; and indeed so powerful at this time seems to have been their influence in the attack, that it was not unusual for the besieger, after preparing his mine, to invite the besieged to inspect it, with a view of inducing the latter at once to surrender.

To return, however, to the Defence : the galleries which had been employed previously to the invention of gunpowder, were found to possess certain unlooked-for advantages after the introduction of its use in offensive mines. It was observed that when a charge of powder was exploded in their vicinity, its surface effect was very much diminished : under such conditions the mine was said to be éventée,—'éventer la mine.' The old galleries also retained their original purpose of informing the besieged of the proximity of the enemy, and enabling him occasionally to break into the gallery, and destroy the works.

The first application of powder in defensive mines consisted of small charges ; the explosion of which, without causing any surface effect, ruptured the besieger's gallery, and suffocated its occupiers : this operation was called 'giving the camouflet to the enemy's miners.' From the employment of camouflets to the introduction of more powerful mines was but a step.

By the explosion of larger charges, not only were the surface approaches of the besieger for a certain distance destroyed, but his galleries, which were at a less distance from the powder than the surface of the ground, were likewise blown in : so soon as defensive mines were thus far perfected, the employment of powder in subterranean operations, which at first certainly favored the attack, became a powerful auxiliary to the defence. It is obvious, that when the besieged had, beforehand, arranged a system of galleries under his glacis, he must necessarily possess many advantages over the besieger, who had to construct his subterranean approaches in

ground already occupied by the mines of the besieged. The attack, in place of advancing simply by furrowing the surface of the glacis, was now compelled to engage in under-ground operations, the progress of which must necessarily be slow, and the issue uncertain: superiority of force no longer availed the besieger, while the surface attacks, brought almost as far as the foot of the glacis, became for a time stationary, and exposed to the near fire of the musketry of the fortress.

To increase still more the advantages of defensive mines, various modes of placing them were proposed for destroying the trench cavaliers, overthrowing the breaching batteries of the attack, and blowing the guns into the ditch. Systems of defensive mines, arranged on different levels, were likewise proposed, with the object of destroying the same works of the besieger several times in succession.*

The experiments of Belidor caused, however, these complicated systems to fall into disuse, and deprived defensive mines generally of some of the advantages they had hitherto possessed. To Belidor is due the discovery, that, by the employment of large charges, the galleries of the besieged could be destroyed from a considerable distance. Before his time, it had been generally conceived that no crater, the diameter of which exceeded twice its depth, could be formed by the explosion of a mine, and the interior effect was also supposed to be proportionally limited; but as soon as the fallacy of this opinion had been exposed by Belidor,—who proved that the radius of rupture with large charges much exceeded the limits usually assigned to it,—the attack received considerable advantages. The besieger availed himself of this increased range, and, by means of it, cleared the ground for a considerable distance around him, without pushing his galleries within the much narrower limit of the mines of the besieged. This, however, will be more particularly explained in the 'Attack of a System of Defensive Mines.' J. W.

Note.—The subject will be treated under the following parts or divisions: 'Practical Operations of Mining,'—'Charges of Mines,'—'System of Permanent Defensive Mines,'—'Attack and Defence of a System of Defensive Mines.'—*Editors.*

PART II.—PRACTICAL OPERATIONS OF MINING.†

The essential difference between Civil and Military Mining is, that in the former the works are, for the most part, carried on at greater depths below the surface of the earth, and in solid rock; whereas military mining is what may be termed superficial, and consequently the miner works through the more recent formations of earths and sands, which, from their little tenacity, he has to support as he advances with wooden linings: it is in the adjustment and fitting of these linings that the chief art of the military miner consists.‡

The excavations made by military miners are, when vertical, called Shafts; when horizontal, or when slightly inclined, and exceeding in dimensions 3 feet by 4 feet, Galleries; when under these dimensions, Branches: when galleries or branches are inclined, they are called ascending or descending, according to the direction of their inclination.

The galleries and branches of a system of mines, forming part of the defences of a fortress, are usually revetted with masonry: their construction and detail will not be included in this part of the subject, but will be explained in describing the 'System of Permanent Defensive Mines,' (Part IV.)

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* This mode of attack was prior to the invention of globes of compression.—*Editors.*

† By Col. Wynne, R.E.

‡ This part is based upon the practical course taught at Chatham.—*Editors.*

The annexed Table gives the names and dimensions of galleries and branches employed in mining operations.

NAME. Description of Gallery or Branch.	Dimensions in the clear.	Scantling of Frames.		
		Groundsill.	Stanchions.	Capsill.
	Height. ft. in. × Width. ft. in.	inches.	inches.	inches.
1. Great gallery . .	6 6 × 7 0	6 × 3	6 × 6	6 × 8½
2. Principal gallery .	6 6 × 3 9	5½ × 3	5½ × 5½	5½ × 8
3. Common gallery .	4 6 × 3 0	none required	5 × 5	5 × 6½
4. Branch	3 6 × 2 6	none required	4 × 4	4 × 5

No. 1. Used for descent into ditches and the passage of cannon.

2. For descent into ditches and the passage of troops, two deep.

3. Sufficiently large for all the general purposes of attack ; and as it allows the miner a free change of posture, to work kneeling either on both knees, or on one knee, with the right or left foot advanced, he works without feeling cramped, and executes a gallery of this size more rapidly than any other.

4. Too small to work in for a greater distance than 10 or 12 feet.

TOOLS REQUIRED FOR MINING OPERATIONS.

Plate I.

Pickaxe (common).
Do. (short-handled), fig. 1.
Shovel (common).
Do. (short-handled), fig. 3.
Push-pick, fig. 2.
Rake, fig. 6.
Canvass bucket.
Windlass and rope, (2-inch).
Rope ladder.
Wooden wedges and pins.
Do. pickets.
Miners' waggon, fig. 5.
Wheelbarrow.
Iron candlestick, fig. 7.
Lamp (miners').
Lantern.
Oil can.
Measuring tape.
Compass.
Universal level, fig. 4.
Hand-saw.
Mallet.
Hammer (claw).
Rough plane (¼-inch).
Chisel.
Gimlet.
2-foot rule.
Plumb-bob.
Boring-rods.
5-foot rod.
Bellows (miners').
Ventilating tube.
Flexible joints.
Needles, threads, scissors.
Calico for hose.
Hatchet.
Tin funnel (for filling hose).
Rammers (short-handled).
Helves (spare).
Sand-bags.

WOODEN LININGS.

It has already been stated that the military miner, from the loose or made soil in which he generally works, has, as he advances, to support with wooden linings the top and sides of his excavation; in some soils, the earth is of sufficient tenacity to require only that, in driving galleries in it, their top should be supported. But in sinking shafts it is always advisable, unless their depth should be very little, to line them with boarding throughout, or at least partially.

In describing the process of driving a gallery, the soil is supposed to be of that nature which renders close casing desirable.

There are two methods adopted at the Royal Engineers Establishment at Chatham for lining shafts and galleries. The first is with mine frames, which, in appearance, are similar to door frames, being cut out of scantling, and placed upright or horizontally at certain intervals in the gallery or shaft, as the case may be, and which serve as supports to planks called sheeting planks, which are placed all round between the frames and the sides of the excavation. The second is with cases, which, instead of being made from scantling, are formed out of plank, about 2 inches thick and 1 foot wide, and when placed close together, serve at once for frames and sheeting. The advantage of this latter method in saving excavation, and consequently expediting the work, is at once obvious; besides which, the facility of fixing them up is much greater: these and other collateral advantages have been so much felt at the Engineering Establishment at Chatham, that cases have quite superseded mine frames in the practice there; but as circumstances may occur which render it more convenient to use frames and sheeting than cases, both methods will be described, commencing with the former.

SINKING SHAFTS WITH FRAMES.

Shaft frames are composed of four pieces, two of which are long and two short.

The long pieces are of the same uniform section throughout; the short pieces are notched at each end, so as to form shoulders for the long pieces to abut against. (See figs. 1 and 2.) The depth of these notches is made equal to one-third of the width of the piece.

Fig. 1.

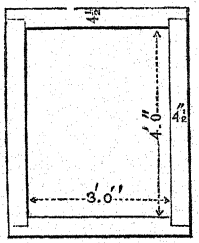
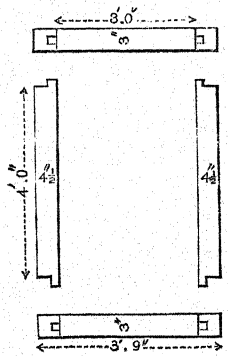


Fig. 2.



To prevent the parts from separating, the long pieces are made with tenons,* and mortises are cut in the short ones, close to the shoulders, to receive them.

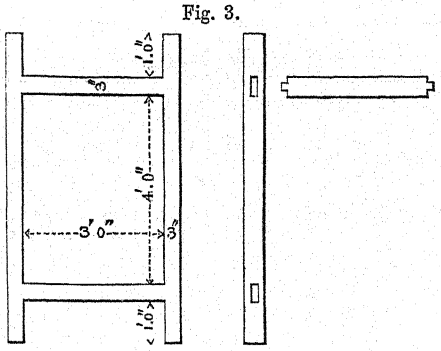
As the tenons or dowels are merely for the purpose of steadying pins, the smaller they are the better, provided they are not liable to break; and they must not be so tightly fitted into the mortises as to prevent the proper bearings and abutments of the parts of the frame against each other: with the same view, it is also essential that each tenon or dowel shall be flush with one side of the piece to which it is attached, and that the mortises shall be cut quite close to the shoulders of the other pieces: the pressure on the frame being lateral, the width of each piece should exceed its

* Dowels of a harder description of wood may be inserted instead of tenons, and they render the frame more serviceable.

depth ; 3″ by 4½″ will be found sufficient for all shafts not exceeding 3 feet by 4 feet ; and this size (3 × 4½) is probably the largest that would ever be required in field operations. For temporary purposes, 4″ by 6″ will be sufficient for a shaft 6 feet in extreme width.*

In addition to the common shaft frames before described, it is proper to have one expressly for the top of each shaft ; its dimensions in the clear are the same as those of the common frames, but the ends of the two long pieces are made to project about 1 foot each way (fig. 3) : the parts of this description of frame are connected by tenons and mortises which are equal in length and width to the whole width of the wood, but in depth to one-third only : the same scantling may serve both for the top shaft frame and the common ones, but not without reversing the position of the pieces ; for in the top frame the depth should be greater than the width.

Fig. 3.



The sheeting for shafts should be of plank from 1″ to 1½″ thick ; the planks are usually chamfered at one end, to admit of their being more easily pushed forward ; their length will depend on the distances at which the frames are placed, which on an average, may be assumed to be 4 feet : the planks may therefore be cut in lengths of 5 feet, which will allow the necessary overlap.

MEN AND TOOLS REQUIRED FOR SINKING A SHAFT.

MEN.		TOOLS.													
		Picks.		Shovels.											
N. C. Officers.	Privates.	Short.	Push.	Long.	Short.	Line.	Level.	Measuring rod.	Mallet.	Canvass bag.	Rope ladder.	Wheelbarrows.	Windlass.	Miner's trucks.	Ventilating apparatus.
1	4 or 6	1	1	2	2	1	1	1	1	1	1	2	1	2	1

It has been found that one man can work in a shaft not less than 4 feet in depth, and throw out earth until it is 8 or 9 feet deep ; after which the earth is drawn up in a canvass bag by two men at top, by means of ropes attached to each of its handles : should the depth become great, a windlass and bucket must be substituted.

The disposition of the workmen is as follows :

1 man excavates and fills the bag.

2 men haul up or work the windlass.

Each one of the four parts of the frame should be notched in its centre on the inside; these notches assist materially afterwards in the proper adjustment of the frame.

1 man fills the wheelbarrow, wheels, and spreads ; or 1 fills.
1 „ wheels.
1 „ spreads, to prevent an accumulation which might attract observation.

Two gauges or rods for the extreme dimension of the rectangle of excavation are to be provided : these two rods must respectively exceed the true exterior dimensions of the shaft frame in length by about 6 inches (3 inches on each side), in order to admit of two* thicknesses of sheeting planks being introduced all round, between the frame and sides of the excavation.

The top shaft frame having, when placed, only one thickness of sheeting planks round it, the rectangle of excavation must be marked on the ground rather less than the dimensions of the gauges. When the shaft is intended to be sunk with a view to the commencement of a gallery, care must be taken that the long sides of this rectangle shall agree with the direction of the proposed gallery.

The distance at which the floor of the gallery is to be placed below the surface of the ground being given, the first thing to be done is to determine the distance to be left between the frames. To find this, let us suppose that a common gallery, 4 feet 6 inches high in the clear, is to be driven from the bottom of a shaft 25 feet deep :

	ft.	in.
Then the height of the gallery from the floor to the top of the capsill being	5	1
Thickness of top sheeting	0	2
Free space for introduction of do	0	2
Thickness of shaft frame next above the gallery . . .	0	4½
	5	9½

The top, therefore, of the frame above the gallery must then be five feet 9½ inches from the bottom of the shaft. Subtract this from the total depth of 25 feet, there remain 19 feet 2½ inches. There would then be required four intervals of 4 feet each, and one of 3 feet 2½ inches for the last interval. To find the length of the last set of sheeting planks, the thickness of one frame and an overlap of 2 inches must be added to 5′ 9½″, making 6′ 4″.

An excavation of the size of the rectangle previously marked must then be cut vertically down to the depth of 2 or 3 feet ; after which, one of the top shaft frames, before described, is placed correctly over the excavation, the projecting pieces preventing it from falling down : this frame is generally placed flush with the surface of the ground. The excavation is then continued to the depth of four feet, when a common frame is put together, and laid horizontally at the bottom of the shaft, with its corresponding sides vertically under those of the upper frame : the excavation at this level must be fully equal to the dimensions indicated by the gauge rods. A plumb-bob is necessary to preserve the verticality of the excavation, as well as for the adjustment of the successive shaft frames by means of the notches before noticed. As soon as the second frame is placed,† the first set of planks are pushed vertically downwards, with their pointed ends foremost, between the earth on each side and the top frame.

At top, each of these planks is pressed home close to the top frame, but at the

* It may be necessary to explain that each set of sheeting planks must project a few inches above and below the two adjoining frames: so that each frame, with the exception of the top one, has necessarily two sets of planks between it and the earth.

† It will seldom be found necessary to close-sheet a shaft; generally two planks on a side will be sufficient. For shafts of moderate depth, and for hasty explosions, woodwork may generally be dispensed with altogether, even in earth of no great tenacity. But when the soil is favorable, shafts of 20 or 30 feet in depth may stand for several weeks. In excavating a shaft in which no woodwork is to be used, the elliptical form is decidedly the best.

bottom it is kept out from the lower frame by wedges rather thicker than the plank itself. The two frames are then connected together by four ties of wood, which are thin laths, about 2 inches wide, extending vertically from one frame to the other, being nailed to each : sometimes rope is used, in which case it is made to pass through holes bored in the frames, and a knot on the rope, or a picket between the strands, immediately under the lower frame, prevents it from falling. (See Figs. 4 and 5).

Fig. 4.

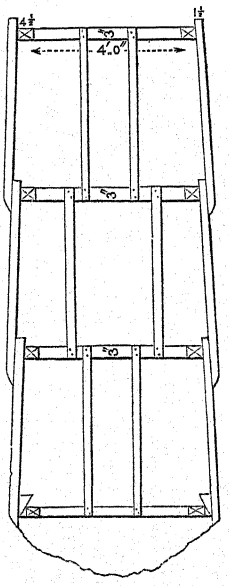
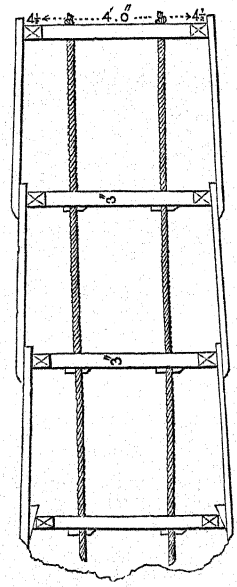


Fig. 5.



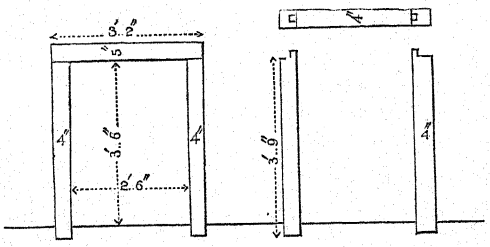
After the first two shaft frames and one set of sheeting planks are thus placed, and the frames connected, the excavation is continued about 4 feet deeper, when another frame is placed with the same care : a second set of planks is then introduced between the first set and the second frame, after removing the wedges which were before inserted : in order to preserve room for them, these new planks are pushed down to the bottom of the shaft, and are there separated from the lower shaft frame by wedges, as before described. Thus the work goes on until the miner arrives near the level of the top of the proposed gallery, when the last shaft frame must be placed at the calculated interval. This being attended to, the excavation is continued down to the bottom of the intended gallery, when another shaft frame is placed so as to have its upper surface on a level with the floor of the gallery. Three sides only of this part of the shaft must now be sheeted, and without wedging out the planks which are to rest against the bottom frames : the fourth side of the shaft being left clear for the entrance of the gallery on this side, the outline of the gallery is traced.

DRIVING GALLERIES WITH MINE FRAMES.

Gallery frames differ from shaft frames in being composed of three pieces only ; namely, two uprights, called stanchions, and one top piece, called the capsill. The stanchions are usually let into the ground a few inches, and the capsill afterwards

laid over them. The stanchions have square tenons at top, flush with the inside of each, which are inserted into mortises cut in the lower side of the capsill. The stanchions are usually cut out of square scantling; the tenon is made equal to one-third of the side each way, and in height to one-fourth. The scantling for the stanchions of a branch may be 4″; for a gallery 3 or 4 feet wide, 5½″ or 6″. The capsill is usually made of the same width as the stanchions, but somewhat deeper for the sake of strength, the chief pressure being vertical. In branches and small

Fig. 6.



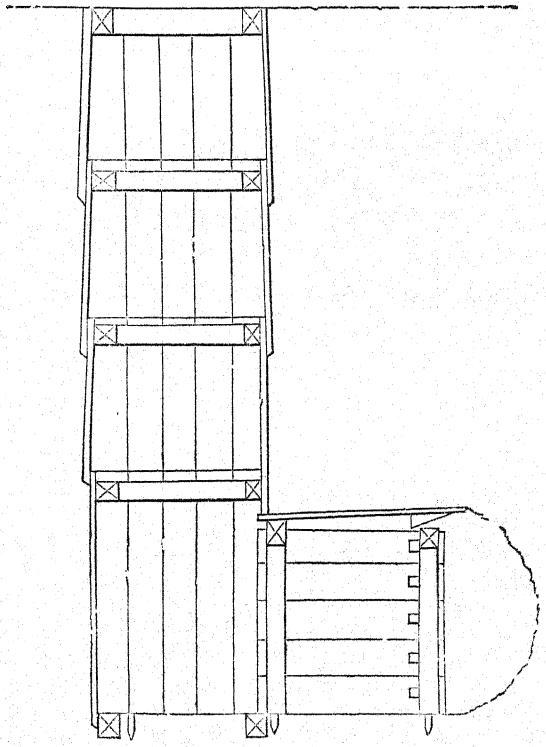
galleries an excess of about one-fourth will be sufficient; in the wider galleries the excess may amount to one-third or even one-half. The side sheeting of galleries may be of 1″ or 1½″ plank; for the top-sheeting it should be from 2″ to 2½″.

Great gallery frames have their stanchions of scantling 5½″ or 6″ square, and their capsills 8″ by 5½″ or 8″ by 6″: the tenons at the head of each stanchion should be 1½″ square and 1½″ long. We shall now proceed to describe the method of driving the gallery from the bottom of a shaft, and we shall consider the ground to be such as to render it necessary to sheet the sides as well as the top.* The first thing necessary is to prepare two rods as gauges for regulating the height and width of the excavation; the gauge for the height must allow beyond the extreme dimensions for two thicknesses of plank, and that for the breadth for four thicknesses of plank, two on each side of the frame; and the latter, *i. e.* the gauge, must be notched or otherwise conspicuously marked in the centre. It was stated before, that in sinking a shaft the long sides of the frames must correspond with the direction of the gallery intended to be driven from the bottom: if this has been carefully attended to, the direction of the gallery will be at once obtained by dropping plumb-lines from the centre of each of the short pieces, and marking these points at the bottom of the shaft with pickets; or the notches on the bottom frames, if accurately laid, will be sufficient. In commencing the gallery, the excavation may be carried forward about 1 or 2 feet before the first frame is placed; the entrance made in the first instance should be less, both in width and height, by the thickness of one set of planks, that is, by 1½″ on each side and 2″ on the top; the exact position of the first frame being ascertained by laying the gauge so that the notch in its centre may coincide with the picket at the entrance of the gallery. The stanchions are first set up with their lower ends inserted a few inches in the ground; the plumb-bob being used to set them perpendicular, the capsill is placed on them, and the frame secured in its upright position by being wedged out from the top and side.

* Although it has been thought advisable to describe the mode of driving a gallery under circumstances which render it necessary to close-sheet the top and sides, it will in most instances be found sufficient (except in the case of great galleries) to sheet only the top: when this is the case, the stanchions of the frames are let into grooves cut in the sides, and by this arrangement a considerable quantity of excavation will be saved.

This being completed, the excavation is continued to the distance of about 4 feet, when the position of another frame must be determined. This is done by stretching a line over the two pickets, or fixed points, before determined, and then driving a third picket in the floor, to mark the centre spot of the new frame. If the gallery is

Fig. 7.



a horizontal one, the top of this picket should be made exactly level with the picket at the entrance; if a descending one, the top of it should be the requisite number of inches below the first picket: this, being accurately done, will be a point to measure from for the height of the under side of the capsill. At this point the gallery must have been gradually widened to the full dimensions of the gauges.

The frame is set up in the manner before described; and in order to secure its proper horizontal position, it must be raised or lowered, as may be required, until the bottom of its capsill is at the same height from the ground as the capsill of the first frame: the common level reversed, with its plumb-bob shifted, must then be applied to the under side of the capsill. If the capsills of the first two frames are carefully placed the other will be easily adjusted by being made to line with them. The top sheeting planks * having been introduced over the first frame, with their pointed ends foremost, are now pushed forwards until they rest also upon the capsill

* If the shaft be only 4 feet in the greatest dimension, and the sheeting planks 5 feet long, they must be got into their position from within the gallery.

of the second frame; wedges are then introduced, as in sinking a shaft, and the side sheeting is pushed on in an exactly similar manner.

MEN AND TOOLS REQUIRED FOR DRIVING A GALLERY FROM THE BOTTOM OF A SHAFT.

MEN.		TOOLS.										
		Picks.		Shovels.								
N. C. Officers.	Privates.	Short.	Pick.	Long.	Short.	Line.	Level.	Measuring rod.	Mallet.	Canvass-bag.	Rope ladder.	Wheelbarrows.
1	5 or 9	1	1	2	1	1	1	1	1	1	1	2

The disposition of the workmen is as follows:

1 man picks.
1 ,, fills the truck, wheels, and fills bucket; or 1 fills.
1 ,, wheels.
1 ,, fills the bucket at the bottom of the shaft, or attaches the truck to the windlass.

3 or 5 men are employed at the top of the shaft, as stated before.

For every 50 feet driven, an additional man and truck become necessary, recesses being cut at the sides to receive the empty truck while the loaded one passes: one additional man will also be required at top, to work the ventilating apparatus. Instead of using a bucket for hoisting up the earth, it is found to be a more expeditious plan to attach the full truck to the windlass. Where the gallery is unconnected with a shaft, the two men working the windlass might be struck off. In great galleries the earth may be removed in wheelbarrows.

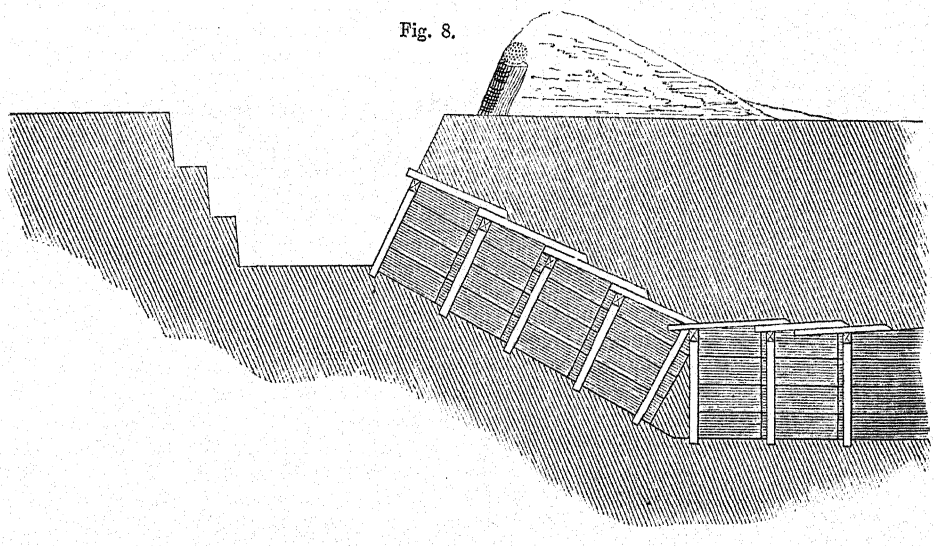
Whenever there appears to be any risk of the soil falling in, it is proper, after placing each successive frame and excavating 1 or 2 feet beyond it, to remove the wedges, and to introduce the next set of top sheeting planks, as far as they will go, without waiting for another frame, and to push them forward as the excavation proceeds. Thus the man excavating will always work under cover of these planks.

INCLINED GALLERIES.

When the depth required to be reached is not great, it will generally be found more convenient to obtain this object by making a descending gallery in preference to striking out from the bottom of a shaft. A gallery is never made to descend more than 1 foot in 2. A descending gallery may be commenced from behind some bank or natural cover, or from behind a parapet; as for example, from one of the most advanced parallels or lodgements in a siege. It may not always be convenient to commence a gallery, when required in a siege, from one of the regular parallels or lodgements; in such cases a small parallel may be made for the purpose, and connected with the nearest trenches by a boyau. When a descending gallery is commenced from a parallel, the trench of the parallel must be deepened at the spot chosen for the entrance of the gallery, as much as may be necessary to allow the top of the excavation of the gallery to be $2\frac{1}{2}$ or 3 feet below the original surface of the ground. The execution of the gallery is to all intents the same as that of a horizontal

one, except that the frames are set up perpendicular to the slope, and the distance between any two must be measured along it. This being attended to, the same sheeting will answer, whether the gallery is inclined or horizontal. The first frame of an inclined gallery ought, as nearly as possible, to be under the terreplein of the banquette. It is to be observed that the pressure of loose earth acting upon the roof of a gallery will always tend to overset the mine frames, unless the latter are placed in a direction perpendicular to the floor of the gallery, or nearly so.

Fig. 8.



In changing from a descending direction to a horizontal one, it is necessary to change also from oblique frames to vertical ones, and it becomes also necessary to support the first vertical frame by struts placed parallel to the stanchions of the oblique frames in rear of it. Thus the capsill of the first vertical frame is as it were supported by two pairs of stanchions, one pair vertical and the other oblique, in order to resist the double action of the loose earth immediately above it, which presses vertically upon the top sheeting of the first horizontal bay, but obliquely upon the top sheeting of the last inclined bay of the gallery.

GREAT GALLERIES,

if executed in bad soil, require some precautions to be taken which may be dispensed with in smaller excavations. The following may be found generally essential.

1st. Sleepers or groundsills should be laid beneath each of the regular gallery frames, to prevent the stanchions from sinking unequally. These groundsills, when required, may be cut out of 3-inch plank. In width and length they must be exactly equal to the capsills of the regular frames : they are always inserted their own depth in the earth.

2ndly. It was before explained, that in bad soil the top sheeting should be invariably pushed forward, in proportion as the excavation proceeds. Now whilst this projection does not exceed a foot or two, no inconvenience arises; but when it exceeds the last-named dimension, the great weight of loose earth acting upon the extreme ends of the planks will often derange them in such a manner as may impede

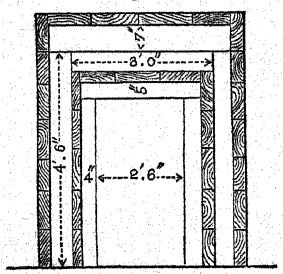
the work, or even cause some serious failure. This difficulty is obviated by using a temporary frame, called a false frame, for supporting the projecting ends of the top sheeting until the roof of every new bay of the excavation is properly secured. The false frame should be of the same height as the regular gallery frames, but it must be so much narrower that its width from out to out shall not exceed the width in the clear of the latter. Its capsill must be of the same depth, but its stanchions must be made of rather smaller scantling than those of the common frame, for the sake of lightness. The method of using a false frame is as follows: as soon as one of the regular or permanent gallery frames is fixed, the excavation is carried forward to the distance of about 1 foot, or even less, according to circumstances, and in no case exceeding 2 feet; after which a false frame is placed in the same manner as a common one. The top sheeting is then pushed forward until it rests upon the capsill of the false frame: the miner then excavates a little further, and pushes forward the top sheeting as he goes on, taking care that it never shall project more than 6 inches, or thereabouts, beyond the false frame, which he must also move forward as the excavation proceeds. As soon as the excavation has advanced to such a distance that another regular frame is required, instead of moving the false one further on, a regular gallery frame is placed, and the same sheeting which rested on the false frame is urged out from it in the usual manner, and the frame removed, for the purpose of being again used in advance. It is to be observed that the false frame, when first placed, must stand about 2 inches higher than the proper position of one of the regular frames, in order that the sheeting, in being pushed or driven towards the head of the mine, may acquire the proper splay upwards without wedges, which it is impossible to use with a false frame during this operation; and for this purpose the stanchions of the false frame must be 2 inches longer than those of the regular ones.

BRANCHES.

In a system of military mines the branches are merely smaller galleries than usual, branching out from the common galleries: hence their name. As the construction of both is so much alike, it is only necessary to notice the circumstances under which a branch proceeding from a gallery may be commenced.

1st. A branch may be excavated in the same direction and in continuation of the gallery itself. In this case the first branch frame must be placed immediately beyond the last gallery frame, and close to it; or, if there be room, it may be placed exactly within it, the centre of both coinciding, as in the annexed figure.

Fig. 9.



2ndly. A branch may be cut at right angles to the gallery from whence it proceeds. In this case the mode of commencing is the same as excavating a gallery from the lower part of one side of a shaft, it being understood that the floor of the branch always commences from the bottom of the gallery. The entrance of the branch is of course cut halfway between two adjacent gallery frames.

3rdly. A branch may be commenced obliquely from the side of a gallery:

In this case, if the soil be good, and not wanting much support, the first branch frame is placed as near to the side (see fig. 11) of the gallery as possible, but at right angles to the direction of the intended new branch. Hence one stanchion only of the first branch frame can agree with the side of the gallery; the other side will be more or less distant from it, in proportion to the degree of obliquity.

If, on the contrary, the ground cannot be trusted, the first branch frame must be placed so as to line with the side of the gallery itself (see fig. 10), and consequently a longer capsill than the ordinary ones will be required.

Fig. 10.

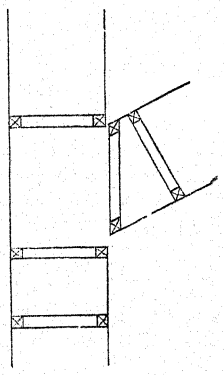
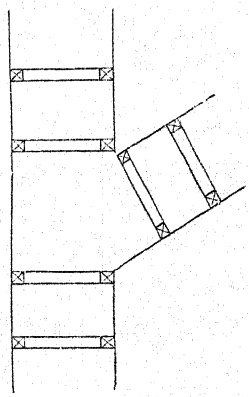


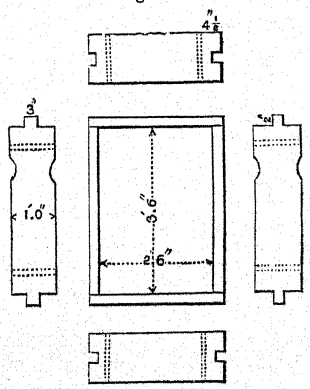
Fig. 11.



MINING WITH CASES.

Having described the method of mining with frames and sheeting, it remains now to point out the difference when mine cases alone are used. These descriptions of cases have long been known under the name of Dutch cases: they were introduced into our Service by Major-General Sir C. Pasley, when Director of the Field Instruction Establishment: they consist of four pieces, — two stanchions, a capsill, and groundsill. For ordinary work they are made out of 2-inch deal, and have a $\frac{3}{8}$-inch round iron bolt driven transversely through the middle thickness of the wood of each piece, about $4\frac{1}{2}$ inches from each end, to prevent them from splitting. The stanchions have tenons 2″ long by 3″ wide at each end, and mortises of corresponding dimensions are cut in the ends of the capsill and groundsill to receive the tenons: the most convenient width for the piece would be 12 inches, but this is not a matter of consequence (as 12-inch is not easily procured), and they may be made of whatever sized planks, not less than 2 inches thick, can most readily be procured. In great galleries, which require stronger materials, the stanchions may be 4 inches thick, the groundsill 3 inches, and the capsill 5 inches: notches, as shown in figure, are cut in the stanchions, for the purpose of rendering them more manageable, both in putting them up and taking them down; they also serve for places in which to drive pickets to support the case in a descending gallery. The size of cases, in the clear, both for shafts and galleries, is the same as that of frames, and the same precautions and arrangements in their adjustments are necessary.

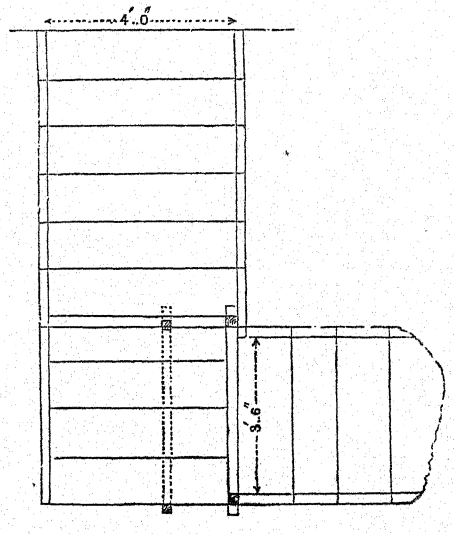
Fig. 12.



In sinking shafts, when the excavation has advanced about 1 foot in depth, it becomes necessary to fix the first case, which is done in the following manner. One of the short pieces is first placed in its proper position in the excavation; the tenons of the two long pieces are then fitted into the mortises of this, and then the mortise at one end of the fourth side is fitted on its tenon; but to adjust the corresponding mortise and tenon, it will be necessary to push back either this short piece or the long one full 2 inches, in order to bring the mortise and tenon together; and whichever plan is adopted, as little earth as possible should be cut away. The first case being placed, the excavation is proceeded with, and the second case is placed close under the first, and in a similar manner, and so on to the bottom of the shaft. This is the mode of proceeding when the soil is so bad as to require close casing; under ordinary circumstances, however, it will be sufficient to introduce a case at every 3 or 4 feet; and when this is done, it is usual to cut out the earth to the thickness of the plank, so as to admit of the case being placed flush with the sides of the excavation.

When it is intended to push a gallery from the bottom of a close-cased shaft, it is evident, before proceeding, it will be necessary to remove one side of the casing; and to do this without causing the adjacent side to collapse, and the casing to tumble in, a frame somewhat similar to a door frame must be introduced: its groundsill being

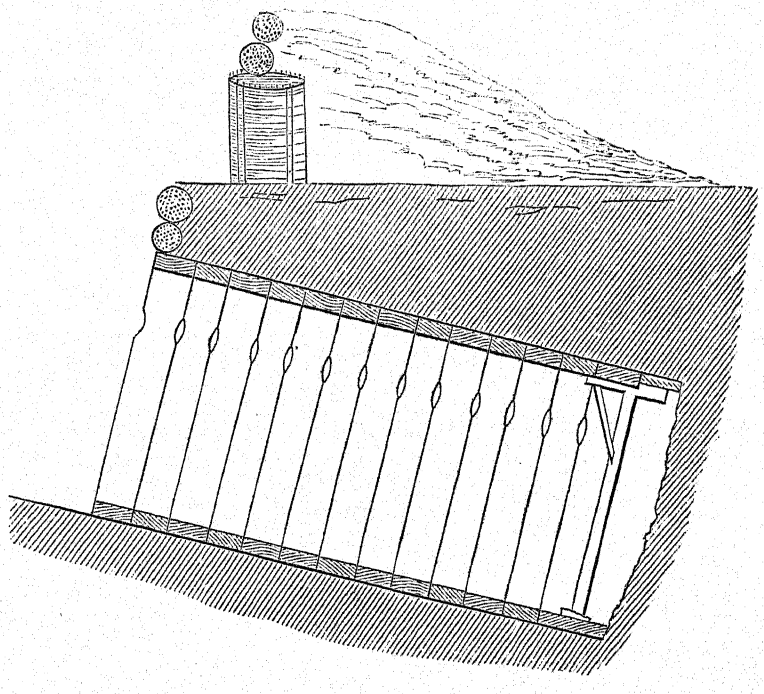
Fig. 13.



adjusted so that its upper side may be on a level with the floor of the intended gallery, the exterior dimensions of the frame must exactly correspond with the width of the shaft, and the interior dimensions may be exactly those of the gallery, or exceed them by an inch or two. When this frame is first put up it should be made to stand about 1 foot from the side of the casing which is to be removed; and when this is effected, it must be forced up against that side. These details having been attended to, the casing on the side from which the gallery is to start may be removed, commencing with the side of the lowest case, to remove which will be a work of some difficulty; as the earth must be picked away from behind it, in order to admit of its being pushed

back to clear it of its tenon, it will be necessary, in the first instance, to excavate the ground underneath it, in order to admit of the introduction of the pick and push-pick, but the removal of each successive side will be easier. In driving the gallery, the mode of using the cases is as nearly as possible similar to that described for shafts, making allowance for the difference of direction : the groundsill is first placed, next the stanchions, and to fix the capsill the same mode of proceeding is to be adopted as has already been described for fixing the fourth side of the shaft case : the space which is necessarily left between the earth and the top of the capsill should be filled in before proceeding to place the next case. Close casing will seldom be required in a gallery, but the roofing should in most cases be supported : this can easily be effected by using pieces of the cases as top sheeting, extending from the top sides of the cases which it may be found necessary to use.

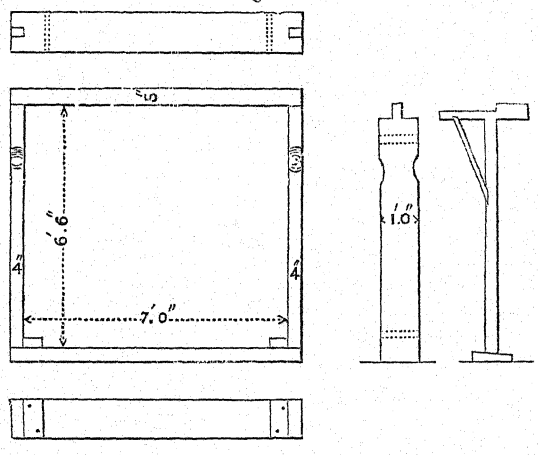
Fig. 14.



Great gallery cases (fig. 15) are somewhat different from other cases. In order to give greater strength, the stanchions are made without tenons at their lower ends, which are kept in their places by cleats 2 inches thick, nailed on to the sills ; the mortises in the capsills need not be more than 2 inches deep. In driving great galleries in loose soil, after setting up the first frame it becomes necessary to support the topsill whilst the miner excavates the ground for the groundsill and stanchions. For this purpose two upright pieces of timber, carrying each a cross-piece, as represented in the annexed figure, are made use of. The upright part rests on the sill of the frame already placed, and is steadied by being wedged up. The cross-piece is 2 feet long, and the part that projects in advance, as will be seen from the figure, is made an inch higher than the rear part, to support the topsill somewhat higher than

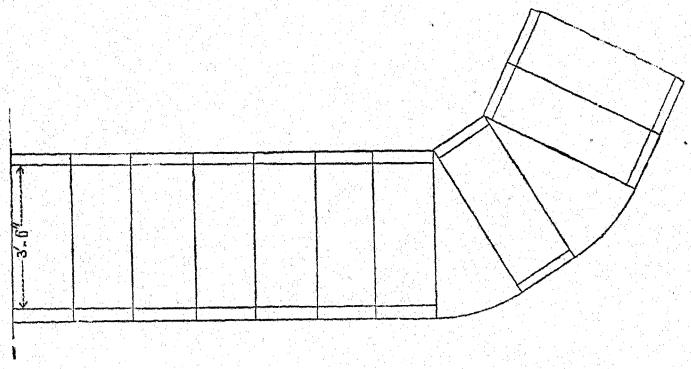
its final level. The rear part of the cross-piece is braced by a piece of iron to the upright. These are called crutches, and the materials of which they are made should be as light as a due regard to strength will admit.

Fig. 15.



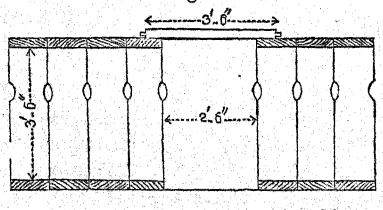
In working with cases, the direction of a gallery may be easily and gradually changed, as shown in plan in figure 16.

Fig. 16.



If the soil is good, the intervals which occur between the cases may be left open; if bad, they may be filled up with small pieces of wood. When it is necessary to break out from the side of a gallery in a direction perpendicular or oblique to it, the requisite number of cases must be removed, and the roof of the interval lined with pieces of board extending across and supported on the extreme cases. See fig. 17.

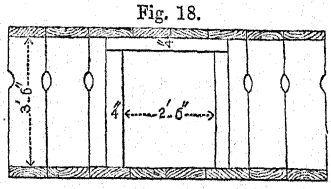
Fig. 17.



If the soil is very bad, the stanchions only from the side whence the new gallery

is to proceed need be removed, and the intervening capsills can be supported as in fig. 18. But this method has the inconvenience of lowering the headway,—a serious objection.

Fig. 18.



When a gallery branches from another in an oblique direction, it will be better to obtain the obliquity gradually, than by introducing an oblique case, like the frame indicated in fig. 16.

When cases are used, the work will advance at nearly double the rate it would with frames and sheeting: viz. great galleries and shafts about 1 foot an hour; common galleries, 1½ foot an hour.

PART III.—CHARGES OF MINES.*

When charges of gunpowder are fired under the surface of the ground, the effects caused by their explosion are necessarily dependent on the quantity of powder used, on the depth at which they are placed, and on the qualities of the soil in which the explosions take place.

When, by the explosion of a charge of powder, a circular excavation is formed on the surface of the ground, the radius is called the radius of the crater. The line drawn from the charge perpendicular to the surface is called the line of least resistance. The line drawn from the charge to the edge of the crater is called the radius of explosion. A crater of which the diameter is equal to the line of least resistance is called a one-lined crater; when the diameter is double the line of least resistance, it is called a two-lined crater; when triple the line of least resistance, a three-lined crater, and so on, the character of the crater being always expressed by the number of times the line of least resistance is contained in the diameter of the crater.

Previously to the experiments of Belidor on the effects of charges of mines, it was generally assumed that no crater could be formed the diameter of which exceeded twice the line of least resistance. It was evident that charges might be so small as to produce little or no effect on the surface; on the other hand, if they were large, the great effect of the explosion would reach the surface of the ground, throw up a certain quantity of earth, and leave a hollow in the form of a cone: it was, also, asserted that there was a certain charge which would produce an excavation, the diameter of which would be double the line of least resistance: if that charge were decreased, a less quantity of earth would be raised; and, if increased, then the earth would be projected higher, but the diameter of the crater would be decreased.

CHARGES FOR TWO-LINED CRATERS, OR COMMON MINES.

The data required for the determination of these charges consist in the form of the crater produced by the explosion, and on the quantity of powder necessary to raise a given quantity of earth and to overcome its tenacity.

Form of Crater.—Various figures have been assigned to the solids raised by the explosion of a common mine. Vauban considered it as a cone the vertex of which was placed in the centre of the charge, and found its volume 1·05 l^3.

Mesgrigny adopted the truncated cone. Le Febvre admitted the cone of Vauban, but added $\frac{1}{7}$ to its volume, which became, therefore, 1·20 l^3.

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* By the late Lieut.-Col. J. Williams, R.E.

Vallière considered it as a paraboloid, having for its focus the centre of the charge, and computed its volume 1·90 l^3.

Müller truncated the paraboloid of Vallière by a plane passing through its focus, perpendicular to the line of least resistance, and found its volume 1·84 l^3.

The form, however, now generally received by miners is that of a truncated cone of which the height of the axis and the radius of the upper or larger circle are each equal to the line of least resistance, and the radius of the lower or smaller circle equal to half that line: its volume then will be represented by $\frac{11}{6}$ l^3.

But whichever of these forms be taken as representing the solid in question, it will be seen that the formulæ representing their volumes do not differ very materially.

The cone of Vauban gives too small a déblai. The paraboloid of Vallière exceeds in volume that of the truncated cone by $\frac{1}{20}$ of the bulk of the latter; while, if the figure of Müller be taken, the excess is only $\frac{1}{276}$ that of the cone, a quantity quite unimportant. The result, then, arising from this similarity in the formula, is, that the rule for ascertaining this part of the calculation remains nearly equal.

The next step in the computation is to determine the quantity of powder necessary to raise a given volume of the earth, as for example, a cubic yard. This quantity will vary according to the weight and tenacity of the soil; but when ascertained by experiment, the rule for determining the charge is obvious, viz. to take $\frac{1}{6}$ of the cube of the line of least resistance for the volume; then multiply the result so obtained (reduced to cubic yards) by the quantity of powder required to raise one cubic yard. This latter quantity being, under different circumstances of soil, variable, the results are also variable. But in ground of ordinary weight and tenacity, it has been found, that by taking $\frac{1}{10}$ of the cube of the line of least resistance in feet, the proper charge of powder for common mines is given in lbs.

CHARGES FOR SURCHARGED MINES, OR GLOBES OF COMPRESSION.

The celebrated French Engineer, Belidor, was the first who employed larger charges than those of common mines, for the purpose of destroying the galleries of the besieger at distances much greater than had previously been supposed possible, and these he called 'Globes of Compression.' Being a Professor in the School of Artillery at La Fère, he had opportunities of making experiments in mining operations, many of which he has recorded.

In 1725 he fired some charges varying from 300 to 3600 lbs.: in 1732 he fired a charge of 1200 lbs.: at Bizi, near Vernon sur Seine, in 1753, at his suggestion, a mine charged with 3000 lbs. was fired by order of Louis XV.; and at Verdun, in 1759, a charge of 4000 lbs. was fired under his direction. It is said that he caused three mines, each charged with 3600 lbs., to be exploded at an equal depth of 12 feet, all of which produced the same effect, viz. craters of 36 feet radius; but there is no record of the date and place of making these experiments. At the siege of Schweidnitz by Frederick the Great, in 1762, where Major Le Febvre, a Prussian Engineer, was the Director of the operations, three large mines were exploded, the greatest charge being upwards of 5000 lbs.

The rules for determining the charges for globes of compression, or surcharged mines, as given by different authors, vary exceedingly.* Belidor considered these charges to be in the ratio of the cubes of the radii of explosion; the rule of General Marescot is to multiply the square of the radii of the craters by the radii of explosion, and then the charges will be in proportion to the products; the rule proposed by

* See "Papers connected with the Duties of the Corps of Royal Engineers," vol. ii. page 20.

Gumpertz and Lebrun accords very nearly with that of Marescot. These authors maintain, that because a certain charge of powder, 3600 lbs., with a line of least resistance of 12 feet, produced a 6-lined crater, and because this same charge, placed at the depth of 33 feet, will only produce a 2-lined crater, the same relation will hold good in all other mines: therefore, to find the charge of a 6-lined crater, under any assumed line of least resistance a, the proportion would be $12 : a :: 33 : x$; x representing the line of least resistance of a common mine, the charge of which will produce a 6-lined crater with a line of least resistance a.

It is stated, also, that the lines of least resistance of other surcharged mines are determined from the above proportion.

The rules of Major-Gen. Pasley, as given in the following Table, are very valuable, having been deduced from experiments carefully made:

CHARGES, AND EFFECTS PRODUCED IN MIXED EARTH.

To find the quantity of powder.	Multiply by	Gives the powder in lbs. to produce No. of lined crater.	Earth thrown out in depth.	Earth affected in depth.	Distance earth or stone is thrown.	REMARKS.
					yards.	
L.L.R.^{3}	$\frac{1}{30}$	1-lined	not defined	. .	. .	The experiments from which these rules were deduced were carried on in a soil weighing from 90 to 122 lbs. the foot cube, and on a L.L.R. of 6 feet.
,,	$\frac{1}{20}$	1½-lined	do.	. .	. .	
,,	$\frac{1}{10}$	2-lined	do.	. .	. .	
,,	$\frac{1}{4}$	3-lined	do.	. .	. .	In not attempting to produce more than 3-lined craters, the charges are nearly certain; in surcharged mines, they are not so certain: it is, therefore, better to use a number of small charges to produce a certain effect, than to use one large one; the latter being very wasteful of gunpowder.
,,	,,	4-lined	L.L.R.	1⅔ L.L.R.	. .	
,,	2½	5-lined	1¼ L.L.R.	2 L.L.R.	180	
,,	4	6-lined	1½ L.L.R.	2 L.L.R.	270	
,,	8½	7-lined	. .	. .	. .	In earth, try to produce 3-lined craters at 2-line intervals, and never with a L.L.R. less than 6 feet.
,,	9¼	7½-lined	1⅝ L.L.R.	2½ L.L.R.	600	

The rule given in Captain Macaulay's 'Treatise on Field Fortification' is the same in principle as that of Gumpertz and Lebrun, but it is based on a different experiment. It is considered that it may be safely adopted in computing the charges for surcharged mines.

The example on which he grounds his rule is as follows.

One of the globes of compression at the siege of Schweidnitz was charged with 5404 lbs. of powder, which, being placed under a line of least resistance of 16 feet, produced a crater of 41½ feet radius.

Let it be assumed that the above globe of compression was exploded in common earth; and let it also be ascertained under what line of least resistance the same charge of 5404 lbs. must be placed so as to produce the effect of a common mine, viz. a crater with a radius equal to the length of the line of least resistance. Now as the charges of common mines are in the ratio of the cubes of their lines of least resistance, the following proportion will be obtained, viz.

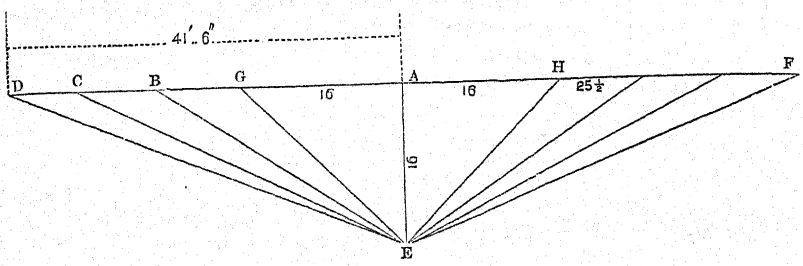
$$\begin{matrix} \text{lbs.} & & \text{lbs.} \\ 100 & : 10^3 :: & 5404 : 54040 ; \end{matrix}$$

and, extracting the root, 37·81 or 37 feet 10 inches is found to be the line of least resistance required.

It will be observed that, in the present example, the charges have been taken as $\frac{1}{10}$ L.L.R^3, and not as $\frac{1}{9}$ L.L.R^3: the latter co-efficient is used in the computation in Captain Macaulay's treatise.

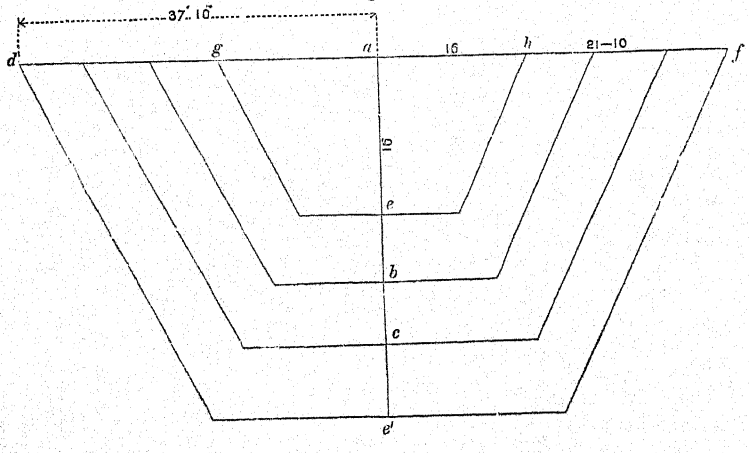
In the annexed diagrams D E F, fig. 1, represents the effect of the globe of compression already alluded to as exploded at Schweidnitz, and G E H that of a common

Fig. 1.



mine under the same line of least resistance, the difference, D G, of the radii of the crater being divided into three equal parts; and *g e h*, in fig. 2, also represents the crater of a common mine under a similar line of least resistance, viz. 16 feet; and *d e′ f*, fig. 2, the effect of a common mine under a line of least resistance corresponding to the charge of 5404 lbs.; the difference, *g d*, fig. 2, between the radii of the two craters being, in like manner, divided into three equal parts.

Fig. 2.



It is evident from a comparison of the diagrams, that if, under a line of least resistance of 16 feet, it is required to produce craters of the radii A B, A C, the charges must be the equivalents of those of common mines with lines of least resistance equal to *a b* and *a c*. From the above reasoning it therefore follows, that a rule for finding the charge for the globe of compression may be thus determined:

Subtract the given line of least resistance (16 feet) from the radius (41½ feet) of the required crater of the globe of compression, and also from the line of least resis-

tance (37 feet 10 inches) of the common mine requiring the same charge; divide the latter difference by the former, viz.

$$\frac{21 \text{ feet } 10 \text{ inches}}{25 \text{ feet } 6 \text{ inches}} = \frac{21{\cdot}83}{25{\cdot}5} = {\cdot}85;$$

then it becomes clear from the diagrams, that if the difference of the given line of least resistance, and the radius of the crater of the surcharged mine, be multiplied by the result of the foregoing division, and that product added to the line of least resistance, the sum gives the required line of least resistance by which to compute the charge.

The general rule, therefore, is to subtract the given line of least resistance from the radius of the crater to be produced; multiply that difference by ·85; add the product to the given line of least resistance, and the result gives the line of least resistance of a common mine requiring the same charge as the globe of compression.

TAMPING MINES.

The tamping of mines consists in filling up the gallery with solid material for a certain distance from the chamber, with a view of preventing the force of the explosion from expending itself in the gallery, rather than in the direction in which the mine is required to act.

The tamping should extend from the charge for a distance equal at least to 1½ times the line of least resistance; and if the material used for forming the tamping be not heavy, or otherwise but loosely packed, this distance should be double of that line.

The materials usually employed in tamping consist of earth which has been excavated in the formation of the gallery,—if free from stones,—or of sods, sand-bags, or any heavy substance which may be at hand. If the soil be argillaceous, it may be roughly moulded into bricks,* which form an excellent material, and one with which the operation proceeds quickly. The most expeditious mode of tamping is, however, generally considered to be with sand-bags.

Split or cleft timber, in lengths of 4 or 5 feet, and of about 9 inches girt, jammed together in the gallery, is also very applicable, and when mixed with common earth at intervals of 10 or 12 feet, forms a good tamping. Indeed, in the demolition of revetments, by an arrangement of mines in an escarp gallery, it would be found sufficient if both extremities of the gallery were tamped with cleft timber.

In tamping wholly with common earth it is desirable to strengthen the mass by pieces of scantling crossing each other, and placed diagonally in the gallery. These pieces of scantling must be secured in their position by letting their ends into the sides of the gallery, or simply by jamming them.

In a permanent system of countermines it is usual to leave grooves in the walls of the galleries, for the purpose of receiving the ends of the scantling above alluded to.

In a common gallery (4½ by 3 feet), the tamping, when executed with common earth and well rammed, will not be completed at a greater rate than from 2 to 3 feet per hour.

In proportion as the charge is increased, the value of the tamping diminishes. Experiments were made by Mouzé for the purpose of determining in what ratio the charge must be increased to produce the same effect with a diminished tamping; and he concluded that when the tamping is diminished by $\frac{1}{5}$ the charge should be

* In some mining operations carried on at Coblentz, by the Prussian Engineers, this mode of tamping was usually employed. In the mining operations executed at Chatham, in August, 1848, the tamping seems to have been composed of walls formed of such bricks, and 3 or 4 feet thick, the intervals being filled with common earth.—J. W.

increased $\frac{1}{4}$; when the tamping is diminished by $\frac{2}{3}$, the charge should be increased by $\frac{1}{2}$; and when the mine is not tamped, the charge should be doubled.

It is often desirable to know the volume of a cubical or other shaped box which shall be capable of containing a given quantity of powder.

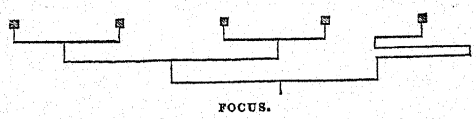
In order to this solution, it is only necessary to bear in mind that a pound of powder occupies a space of 30 cubic inches, a dimension from which the required size of the box to contain a given quantity of powder can at once be determined.

FIRING MINES.

Mines may be fired, or, as it is technically termed, sprung, by a powder-hose, by Bickford's fuze, by the voltaic battery, or by the magnetic coil.*

The powder-hose consists of a tube of strong linen, reaching from the chamber to the outside of the tamping. To protect the hose, it is enclosed in a hollow wooden case represented in profile as follows:  the exterior dimensions of the case being 3 inches, and the interior 1½ inch. The case is fastened to the side of the shaft or gallery by wooden pegs; and in galleries and branches, after it has been secured, it is usually covered with earth, to prevent accidents during the operation of tamping. The mine is fired by a piece of port-fire inserted into the end of the powder-hose, of such length as will give time to the man who fires it to escape before the explosion takes place. The port fire is then covered all round with moist clay, well kneaded with the hands; and earth is applied round all, so as to render it impossible for any fire to communicate with the powder-hose till the port-fire shall have burnt out.

When it is desired that several mines should explode simultaneously, being fired from one point, it is necessary that equal lengths of powder-hose should extend from the focus or point of ignition to all the mines.



Mode of arranging the hose for simultaneous combustion.

To effect this object, the hose of the mines nearest to the focus must be bent more frequently than those leading to the more distant ones, as in the annexed diagram. The bendings of the hose hasten the progress of ignition, but only in a very small degree,—so small as to be safely neglected.

Bickford's fuze consists of a train of gunpowder enveloped in the strands of a rope which has been steeped in a peculiar composition, and the rope protected by a coat of pitch: it is not injured by damp, and will burn under water; it burns at the rate of 12 feet in five minutes. This fuze is very generally used at Chatham: the French employ a very similar fuze introduced by Captain La Rivière, of the French Artillery.

The rocket is also employed to fire the charge. Like the powder-hose, it requires a case or hose-trough. Wherever a change of direction takes place in the case, care must be taken that it is not made too quickly. At each angle it is usual to place a fresh rocket, with its quick-match secured round a nail: the first rocket, arriving at the point where the second is placed, fires it. In order better to insure the first rocket firing the second, a quantity of powder should be strewed about the match of the latter, protected by a triangular slip of deal, nailed to the bottom of the trough: the first rocket then ignites the powder, and so fires the second, which its rapid motion might otherwise fail to do.

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* See the article 'Voltaic Battery, Electricity, Galvanism,' &c.

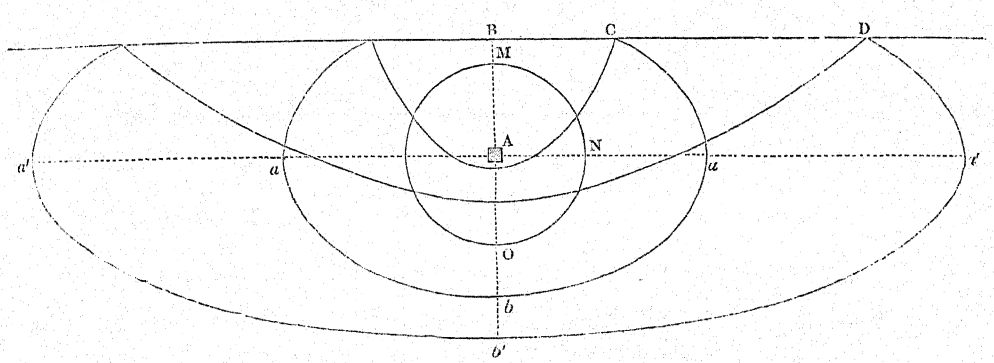
PART IV.—SYSTEM OF COUNTER OR DEFENSIVE MINES.*

In the language of Fortification, the term Mine applies to every subterranean defence; † and in *a system of countermines* are included the galleries, branches, and chambers, placed under the glacis, or other parts of a fortification, with the view of augmenting its strength.

Previously to describing a system of Counter or Defensive Mines, the effect of an explosion of gunpowder under-ground should be explained, as the results therefrom form the data on which such systems are principally founded.

If a charge of powder, A, fig. 1, be placed at a certain distance, B A, below the surface of the ground in a homogeneous soil, and feebly charged, its effect, when

Fig. 1.



exploded, will be to produce a spherical compression, M, N, O, of the earth, whose radius is smaller in proportion as the charge is reduced.‡ This sphere of rupture, M, N, O, is, in the language of miners, termed a 'camouflet.'

If the charge be augmented, a crater will be produced; and, under this supposition, the elastic fluid, generated by the explosion, finding a less resistance to its expansion in a vertical direction than in a subvertical, or downward and lateral, the solid of rupture, or, in other words, the space within which the soil is pulverized and the galleries destroyed, is no longer a spheroid, but an ellipsoid, or at least some analogous solid.

As has been already stated in the article 'Charges of Mines,' the mine is called an ordinary or common mine when the radius B C of the crater is equal to the line of least resistance B A: it is said to be surcharged when the radius B D of the crater is greater than the line of least resistance. It is not practicable to form a crater whose radius exceeds three times the line of least resistance, but the power of producing an interior or rupturing effect appears without limit.

In the ellipsoid of rupture produced by the explosion of a common mine, unity representing the line of least resistance B A, then the terms for the semi-axes are, A $a = 1{\cdot}7$, and A $b = 1{\cdot}3$.

For a mine with a maximum charge, or one where the radius B D of the crater is

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* By the late Lieut.-Col. J. Williams, R.E.

† "On appelle mines en général, tout chemin pratiqué sous terre."—Bousmard, tome ii. p. 88.

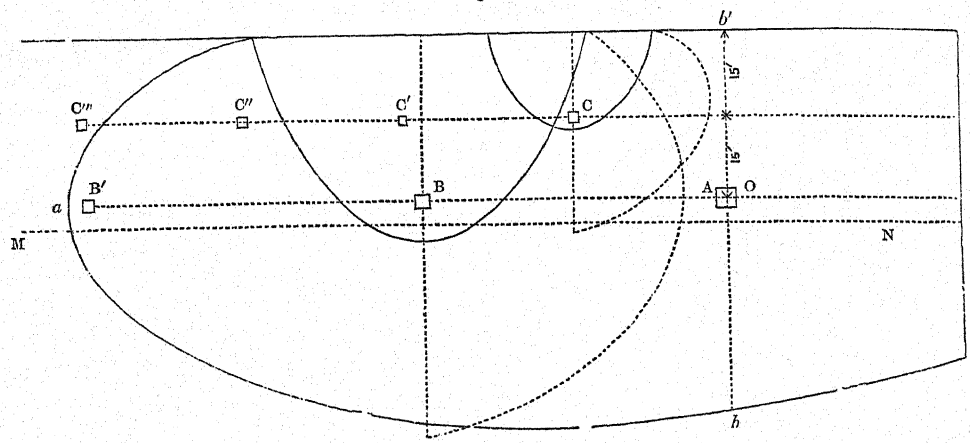
‡ See 'De la Fortification Permanente,' by Dufour, page 151.

three times B A, it is found that A $a' = 4{\cdot}36$, and A $b' = 1{\cdot}40$; that is to say, the semi-major axis of the ellipsoid of rupture is about four times the line of least resistance, while the semi-minor axis is represented by $1\frac{1}{2}$ times that line.

It thus appears, that by increasing the charge, the effects *below* the mine are but slightly augmented; but *laterally* they range considerably further.

Let now M, N, fig. 2, represent the water level, and B, B′ two mines placed as low as practicable as regards the water level, which mines are supposed to be 30 feet

Fig. 2.



below the surface of the ground; let C, C′, C″, C‴ be the position of defensive mines placed at half the depth of the first mines B, B′, and, like them, separated from each other by intervals equal to twice the line of their least resistance.

The besieger, in driving his gallery as low as possible, would place his mines as near as he deemed prudent to the defensive mines B and C, and load them as Globes of Compression, or Surcharged Mines. The solids of rupture of the defensive mines B and C are represented in fig. 2 by dotted ellipses.

It will be observed that they keep off the besieger's third parallel equally distant from the covered-way, when the most advanced mine (C) of the upper system is carried forward a few yards in front of the most advanced mine (B) of the lower system. The besieger's miner then, endeavouring to give to his offensive mine (A) the greatest possible destructive action, would load it with 6000 or 7000 lbs. of powder, which would give to its horizontal radius of rupture a value equal to four times the line of least resistance, while the vertical radius of rupture would somewhat exceed that line.

But as in ordinary or common mines the semi-axes major of the ellipsoid of rupture may be practically taken at about $1\frac{1}{2}$ times the line of least resistance, it follows from the figure, that from B′ to O the distance is about $3\frac{1}{2}$ times the line of least resistance; and that, consequently, the second mine B′, as well as the first mine B, would be destroyed by the same explosion.

In regard to the upper system of mines, there will be three of them within the circle of destruction of the mine A; the fourth, C‴, being exterior to the ellipsoid of rupture, might be shaken, but would not be destroyed. Therefore, by the explosion of the besieger's globe A, supposing all the defensive mines shown in the figure to be

charged, the two lower ones, B, B′, containing each 2700 lbs.* of powder, will occasion a loss of 5400 lbs. to the besieged; while the four higher mines, C, C′, C″, C‴, containing only 337½ lbs., would entail only a loss of 1001 lbs. If also the extra tamping be taken into account, as well as the framing for the galleries, which is necessarily more considerable in two large than in three small ones, it will be found that the same explosion of the besieger will cause to the besieged, when his mines are established deep, a loss at least fivefold greater than what he would have suffered if his chambers had been placed at one-half of the same depth. Thus, therefore, under the inevitable losses which the besieged must necessarily experience, the defensive disposition, C, C′, C″, C‴, appears to have obvious advantages over that offered by B, B′.

On the other hand, the mine C, from its downward or subvertical action, will prevent the besieger from passing below it, and equally prevent him from advancing beyond the line *b b′* as the mine B does: both mines B and C would reach the enemy, if he passed the line *b b′*, with this difference, however, that the mine C would employ—so to say—all its force advantageously at an expense of 337 lbs. of powder to the besieged; while the other mine (B), expending a part of its effort in destroying the tenacity of the ground below, would cause an expenditure of eight times as much powder as mine C. It is from not having considered the effects of mines in a *subvertical* or downward direction, that authors on this subject have fallen into the error now controverted, viz. "That the Besieged ought always to occupy the lowest position for his mines." The superior disposition will require, it is admitted, galleries pushed more in advance, and will cost consequently more, all other conditions remaining the same; but can an expense incurred at the time of the construction of the defensive mines be compared with that which results from a considerable consumption of powder at a period of the siege when it is generally found to be deficient, and when no means can be resorted to for renewing the supply? and, besides, this prolongation of the galleries is not lost to the besieged, since the enemy, who generally is aware of the depth at which the mines are situated, would establish his third parallel at a distance from the rest of the glacis proportionably greater.

If to these advantages, which a system of mines situated at a moderate depth possesses, are added those of a readier mode of tamping, of greater salubrity, by getting rid of the water, and of economy in their first construction,—an economy due to the galleries being nearer the surface, which allows them to be constructed in cuttings, instead of by the laborious process of tunnelling,—it will, it is conceived, be conceded that no doubt can exist of the advantages of the two systems, C, C′, C″, C‴, and B, B′ (fig. 2). The upper system will therefore be selected as situated at the most appropriate depth for the subterranean defence; and the principle will be assumed, that the chambers of defensive mines should be in the same plane, at a depth of from 12 to 18 feet below the surface. The position of the galleries which conduct to them should be in another plane, passing through the bottom of the ditch at the foot of the counterscarp, and rising at such an inclination as to intersect the plane of the mines under the foot of the glacis. The plane of the galleries will therefore be favourably disposed for draining off the water, and keeping them dry.

The mines, disposed as above explained, may be placed in the gallery when the latter is coincident with the plane of the mines; but generally the mines are reached by branches driven from the main galleries.

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* One-tenth of the cube of the line of least resistance in feet.—J. W.

DESCRIPTION OF THE GALLERIES.

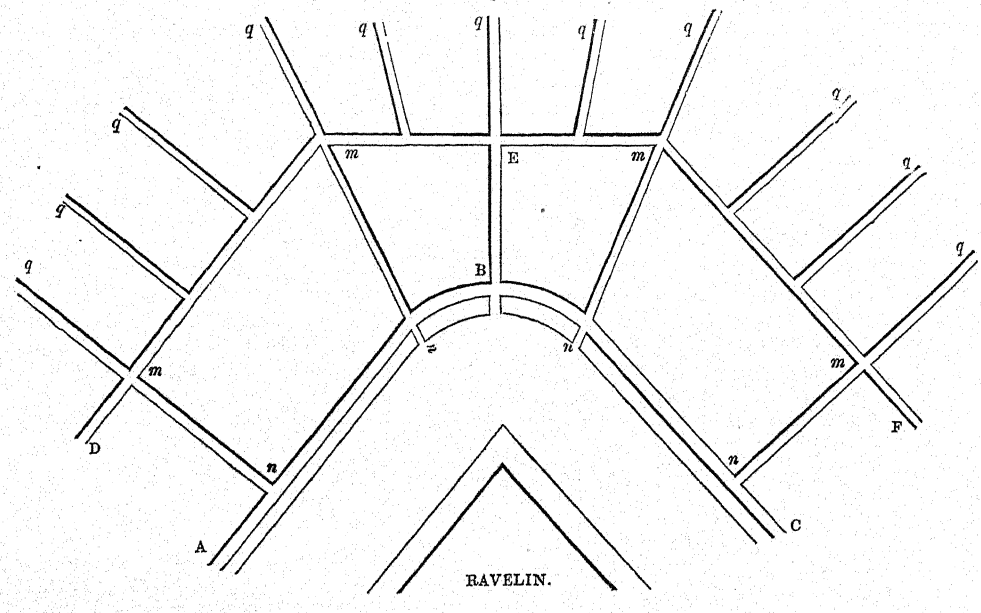
After having laid down the foregoing principle, there remains to be given a description of the galleries and branches, and to explain how *they* should be distributed in a work which it is intended to defend by mines.

The name of Magistral Gallery is given to the gallery A, B, C, which serves as a base to the system of defensive mines. The gallery D, E, F, which is parallel, or nearly so, to the Magistral Gallery, and surrounds the work which it is intended to defend, is termed an Envelope Gallery : all the galleries marked *m*, *m*, which lead from the Magistral to the Envelope Gallery, are termed Galleries of Communication ; and those marked *q*, *q*, &c., advanced into the country, and presenting their ends to the enemy, are termed Listening Galleries (fig. 3.)

MAGISTRAL GALLERY.

The Magistral Gallery has occupied different positions in different systems of defensive mines, viz.—under the banquette of the covered-way ; under the middle of the terreplein of the covered-way ; and, also, immediately behind the counterscarp

Fig. 3.



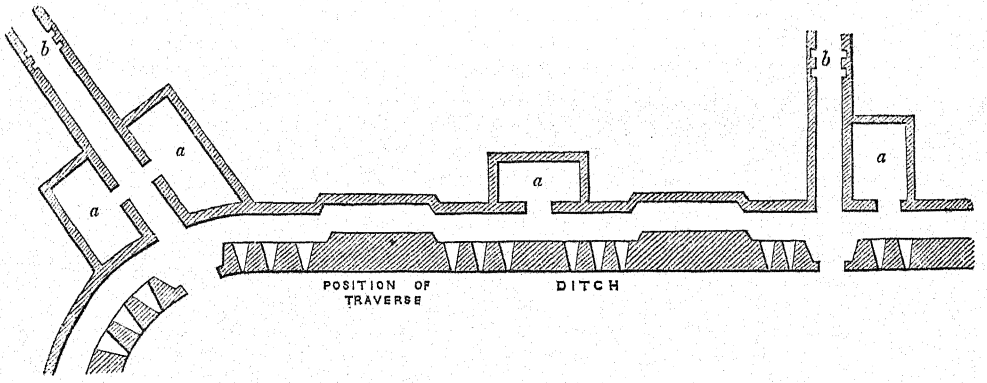
wall. It is now generally admitted that its best position is immediately in rear of the counterscarp wall : so placed it has the advantage of economy of masonry ; it is better lighted and ventilated, and is less exposed to the destructive effects of the globes of compression employed in the attack. In this position it is termed the Counterscarp Gallery.

The Counterscarp Gallery is not in a straight line, because the thickness of the masonry under the traverses is greater than in the other parts, as shewn in fig. 4.

Wherever the thickness of the wall is diminished, loopholes are pierced in it, which,

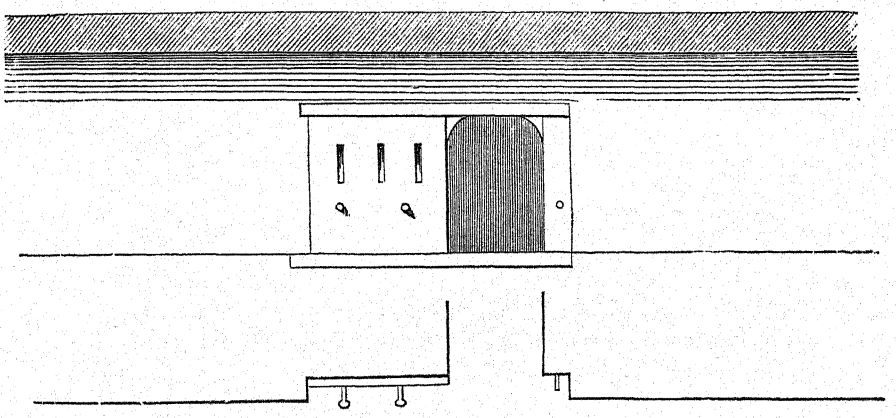
looking into the ditch, have the advantage of defending it by a reverse fire of musketry, at the same time that they admit light and air into the gallery. The entrances into the counterscarp gallery from the ditch, and which are placed opposite to the galleries of communication, are formed with narrow doors, which doors can be bolted in the inside of the gallery: this arrangement permits the defenders to isolate themselves in

Fig. 4.



the gallery, should the attacker succeed in obtaining momentary possession of the ditch. Small magazines, marked *a*, *a*, *a*, *a*, (fig. 4), are constructed as frequently as possible, but principally at the entrances of the galleries of communication; these magazines are convenient recesses for holding tools, the frame-work of galleries, and sand-bags for tamping. The driest and most secure of these small magazines are appropriated for the powder used in the mining operations. Sliding loopholed doors afford means of cutting off the gallery of communication from the counterscarp

Fig. 5.—Plan and Section.



gallery when the enemy has possessed himself of the former. These doors are covered with plate iron, and are represented in fig. 5. They are moved by two handles, and are fastened by means of iron pins, which pass through the door into the wall.

The Counterscarp Gallery should be 6 feet broad and from 8 to 10 feet high.

ENVELOPE GALLERY.

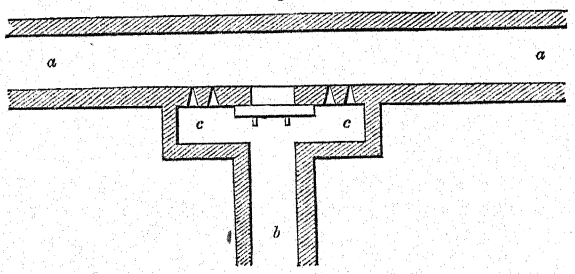
An Envelope Gallery has the great defect of presenting its sides to the Globes of Compression of the Besieger, and, from its advanced position, is liable to be easily destroyed. But as it serves as the base of more advanced defensive galleries, it follows, that all these galleries become useless when the besieger has succeeded in destroying the envelope gallery towards its two extremities. The envelope gallery has, also, the inconvenience of serving as a base to the besieger's miner, after he has gained possession of it. He will push forward his subterranean operations with so much greater facility in working from the envelope gallery, which will contain all the material, &c., necessary for the construction of his galleries. The miners of the besieged and the besieger would then meet on equal terms, which equality is certainly contrary to the spirit of a good defence.

It has also been urged against envelope galleries, that they cannot be enfiladed by the guns of the fortress, and that they serve as a trench to the besieger. But this does not seem a valid objection; for it appears impossible to enfilade a gallery, nor can it be conceived that such gallery, placed at 15 to 18 feet below the ground, could serve the enemy as a trench. However this may be, the objections previously cited are sufficient to condemn envelope galleries, and to abolish them from projects of defensive mines. They ought to be employed only when introduced in small portions. These small portions of envelope galleries, when it is judged proper to employ them, should be 6 feet high and 4 feet broad.

GALLERIES OF COMMUNICATION.

Galleries of Communication exist wherever there are Envelope Galleries, or portions of Envelope Galleries; or otherwise, they extend from the Magistral Gallery to the position occupied by the Envelope Gallery. Their dimensions are the same as those of the envelope gallery, because, like it, they should be adapted to an active circulation, and serve as temporary dépôts for the tools and materials necessary for preparing the mines and for completing the tamping. At certain intervals, grooves, *b*, *b* (see fig. 4), are left in the brickwork of the galleries generally, in order to have the power of interrupting the communication by a barricade of beams, strengthened with sand-bags, when the besieger's miner has arrived as far as the envelope gallery. These

Fig. 6.



small barricades serve also to increase the effect of the explosion of a mine when circumstances require that it should be hastily sprung.

In case of a sudden irruption of the besieger's miner into the envelope gallery, it would be advisable to have the means of closing the galleries of communication, at

their junctions with the envelope galleries, by sliding doors, moveable in the same way as has been described in fig. 5.

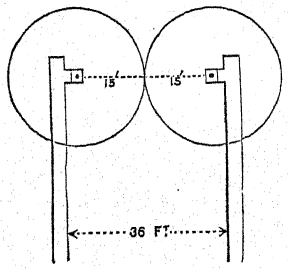
In the annexed fig. 6, *a*, *a* represents the envelope gallery, and *b* the gallery of communication : the recess, *c*, *c*, is necessary to the working of the sliding door, and would serve as a dépôt for tools so long as the besieged remained master of the gallery, *a*, *a*. The loopholes on each side of the door would allow of pistols being employed to defend the door.

LISTENING GALLERIES.

It is by means of Listening Galleries, which are pushed forward as far as the foot of the glacis, and sometimes further, that the besieged informs himself of the approach of the attack : placing his ear close to the ground, he hears the sound of the blows of the enemy's tools, judges of the direction of his approach, and commences a small branch to take the miner in flank. It is from these circumstances that these galleries have been termed Listening Galleries.

The sound of the enemy's pickaxe can be heard only at a distance of about 60 feet; and for this reason the listening galleries should not be separated by intervals greater than 100 to 120 feet, in order to prevent the besieger's miner passing between them unheard. The distance of 120 feet will then be the maximum distance between the listeners. But these galleries are not only destined to warn the besieged of the enemy's approach, but upon them principally depend the whole of the subterranean defence. If, then, a mine is supposed to be prepared in each of two consecutive listeners, and that these mines have a line of least resistance of 15 feet, they would, when exploded, raise the whole space included between the two listeners, if the latter were separated by 36 feet centre interval.

Fig. 7.



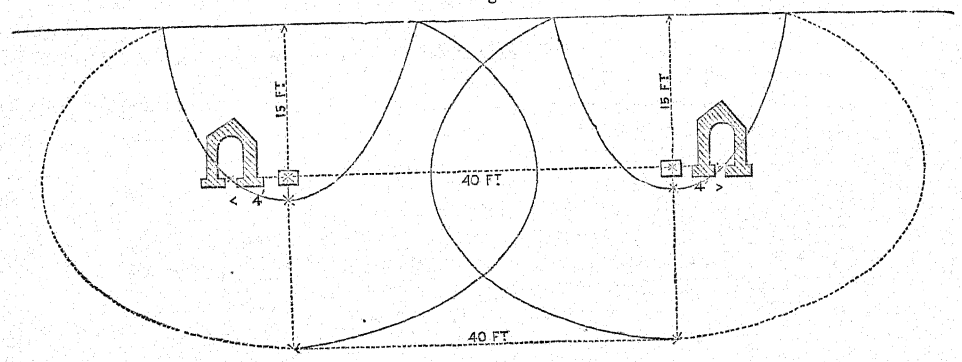
But if it be remembered that the destructive effect of a common mine extends in a horizontal direction $1\frac{1}{2}$ times the line of its least resistance, it is evident that the listeners may be placed at central distances of from 45 to 54 ft., that is, from the centre of one gallery to the centre of the next; and, thus disposed, equally prevent the besieger passing between them. It will be considered, then, as laid down, that with the mean depth of 15 feet, which appears best adapted for defensive mines, two parallel listeners should be placed apart at about central intervals of 48 feet; and, in this position, the following figure (8) shows by a profile how the mines defend the interval, and how deep it would be necessary for the besiegers to go, in order to avoid their effect. The chambers of the mines are at 40 feet intervals, the distance of 48 feet between the listeners being reduced by the length of the two small branches which lead to the mines from the galleries.

Listeners cannot be pushed very far without becoming untenable from bad air. Experience has shewn that the air becomes altogether unfitted for respiration when the head of the gallery has advanced 130 feet. It is necessary that the disposition of defensive mines should be arranged so as to procure currents of air, and that no galleries have a greater length than 120 feet without being crossed by another.

The listeners, presenting their ends to the enemy, are the best disposed to escape, as far as is possible, the destructive effects of globes of compression. Whenever the besieged ascertains that the besieger is preparing a globe of compression, which will be

exploded at some distance from the head of his own listeners, he makes use of his most advanced mines in those listeners, not to crush the enemy, who is out of reach of a common mine, but to make a sort of rupture or cut in the soil, so as to deaden the effect of the globe of compression, the force of which would be diminished by acting in a soil already loosened and shaken. Such is the first effort of defensive mines; its

Fig. 8.



purpose is simply to neutralise to a certain extent a blow which menaces them. But after the first globe has been sprung, and after all the evil it can produce has been felt, and when the direction the besieger's miner has taken on leaving the vast crater produced by the globe has been discovered, then the besieged prepares a new mine, either in the listening gallery or in a branch leading out of it; and as this defensive mine in the branch may be exploded before the besieger has prepared his second globe of compression, the garrison take the offensive, and spring this mine, which will perhaps crush the enemy's miner, or at least delay very considerably his operations.

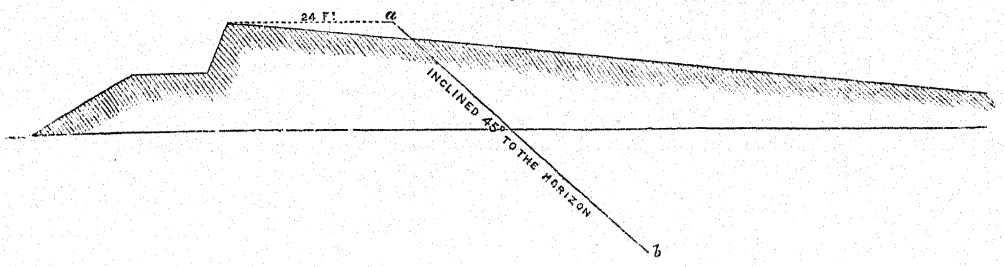
From what has been already stated, it is evident that when a defensive mine is placed behind the masonry of a listener, or at the extremity of a short branch leading from it, the listening gallery itself requires to be tamped: it is necessary, therefore, that it should have such dimensions, that while it admits of a tolerably easy communication, it may not be so large as to demand great labour in tamping. In order to fulfil these two conditions, listeners are generally made 3 feet high and 2 feet 6 inches wide.

To facilitate the execution of branches from the listening gallery, openings are left at the time of their construction, at intervals of about 30 feet, in the side walls, having the same dimensions as the branch; and in order to prevent the earth from falling into the gallery through these openings, they are closed by a thin masonry wall, about 4½ inches thick, which can easily be removed when it is required to commence a branch from the gallery. Grooves about 4½ inches deep are also left in the walls of the listener at intervals of 8 or 10 feet from each other: these grooves form a support for beams of timber placed diagonally across the gallery,—an arrangement which strengthens the tamping, and saves time in its execution. This economy of time in the preparation of the mine is to the besieged of the greatest importance, as it will frequently enable him to spring his mine before the besieger is ready with the globe of compression, which would entail the loss of the powder with which the latter was charged, and retard by many days the progress of the subterranean attack. With the same view of the economy of time, the probable position of the chamber of a mine

should not be more distant than 12 feet from the nearest listener, from which a branch may be driven in twenty-four hours. The best arrangement would certainly be to dispose the listening galleries so near to each other, that a mine fired from behind the side wall of the listener would destroy the besieger's gallery in whatever position it might be; but such a system of defensive mines would multiply the number of listeners too largely, and the advantages would not be commensurate with the increased cost of construction.

It must be understood that the besieged may place charges in any position in the galleries themselves, or in branches leading from them. Care, however, must be taken in determining the places of those nearest the covered-way, that by their explosion the

Fig. 9.



crest of the glacis is not blown away, and the defenders of the covered-way exposed. The chambers of the mines alluded to, whatever may be their depth, should be in a plane inclined 45° to the horizon, parallel to the crest of the glacis, but passing 24 feet from it; so that after the explosion, there will remain 24 feet thickness of earth as a parapet to the covered-way.

The mines placed nearest the covered-way are in a plane of which $a\ b$ is the vertical trace.

They are intended to blow up the breaching batteries of the besieger, should he have had the imprudence to construct them without possessing himself of the ground below. Their position being determined, the branches leading to them may be constructed beforehand. It is not usual to establish mines in the covered-way, because the besieger does not usually lodge himself there, and because their explosion would probably facilitate the descent of the ditch.

ARRANGEMENTS ADOPTED AT THE JUNCTION OF GALLERIES TO FACILITATE THE COMMUNICATION AND INCREASE VENTILATION.

At the point of junction of two principal galleries, as that of an envelope with a gallery of communication, it is usual to construct small vaulted chambers, as are represented in figs. 2, 3, and 5. Plate IV.

These chambers are necessary to facilitate the communication at the junctions; they serve as entrepôts to the miners for their tools and materials; they afford, also, stations for the workmen, who wheel in the earth in barrows, and then fill the sand-bags for tamping. In order to improve the ventilation, the vault is sometimes pierced at the top (communicating with the surface of the ground) by a cylindrical orifice, 3 or 4 inches in diameter (see fig. 2). The chambers are occasionally circular, as shown in fig. 2; or rectangular, when the galleries cross each other at right angles (fig. 5); or lozenge shape, when the galleries cross each other obliquely. In the first arrangement, the chamber or junction of the galleries is covered by a dome; in the

second and third, by groined arches: at any junction containing more than two galleries, the chambers should always be circular.

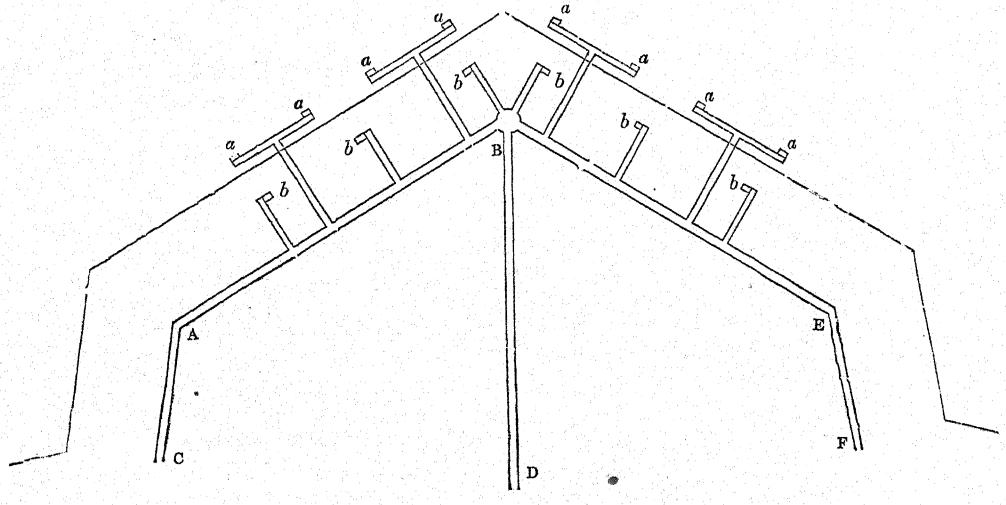
There is another description of chamber, which is sometimes made in the middle of long galleries, in order to facilitate the communication between them. This chamber (fig. 4) affords all the conveniences of that at the junction of galleries, and consists simply of an increase in the breadth of the gallery, covered by a cylindrical arch higher than that of the gallery, but concentric with it: the gallery, at that part of it which forms the chamber, is set back on each side about 2 feet, being a breadth sufficient to allow of the miners with their loads passing each other.

The chamber also affords the means of closing the gallery by a door with one leaf (*a b*, fig. 4) when it is desirable to stop all communication suddenly.

MINES FOR THE DEFENCE OF THE BODY OF THE PLACE.

It is not only under the glacis of the fortress that defensive mines are constructed; employment should also be made of their powerful aid to retard the besieger, giving the assault to, and establishing a lodgement on, the bastions. With this view, a gallery is constructed parallel to the escarp of the face of the bastion, and about 20 yards in rear of it (see fig. 10), communicating with the ditch of the interior retrenchment,

Fig. 10.



or with the interior of the fortress, by means of a gallery on the capital B D, and by two galleries A C, E F, parallel to the flanks. The galleries A B, B E, serve as a base to a system of branches leading to mines *a*, *a*, *a*, *a*, *b*, *b*, *b*, the former being situated under the ruins of the probable position of the breach, and the latter under the lodgements usually made by the besieger on the crest of the breach. The mines of the first series are intended to blow away the earth brought down by the fall of the escarp; and as these mines should be a little surcharged, the débris would be projected violently against the besieger's works, and the breach become impracticable. The mines *b*, *b*, *b*, should be sprung at the moment of assault, in order to bury the besieger amidst its ruins, or to destroy the lodgement which the latter may have succeeded in establishing on the summit of the breach.

The mines *a*, *a*, *a*, *a*, are constructed sufficiently low, while the others, *b*, *b*, *b*, are placed at half the height of the revetment. (See profile given in Plate V. fig. 6.)

It is necessary, then, that the escarp gallery A (fig. 6), which represents the profile of the system, should be placed at such a level that it may not require too quick a descent in order to reach the mine B, placed at the foot of the breach, nor too rapid a rise to gain the mine C. If it be supposed, for example, that the height of the escarp is 30 feet, that the mine C is placed at half that height, that the mine B is 9 fee
Plate V. below the bottom of the ditch, and that the escarp gallery is 20 yards from the back of the revetment, then the floor of the latter gallery ought to be raised about 6 feet above the bottom of the ditch, in order that the branches A B and A C may have slopes of equal inclination.

Fig. 6 also shews the effects of the mines B and C on the ramp of the breach.

A communication is sometimes established between the escarp and counterscarp galleries by means of a passage under the main ditch; but this sort of communication is not convenient, as it can only be entered either by a ladder or a quick ramp: moreover, it is liable to be filled with water, and made impassable.

This arrangement has, however, some advantages, when there is a wish to dispute the descent into the ditch by mining operations; because the gallery in question forms a concealed and covered passage to the scene of the miner's operations. Without this under-ground gallery, it would be necessary, under such circumstances, to cross the main ditch, exposed and unprotected, in order to gain the counterscarp gallery; and as the besieger occupies the covered-way, this would be a service of great danger. It is, however, to be remarked, that the counterscarp gallery runs throughout the whole extent of the counterscarp, by which means it may be entered at distant points from the front of attack, which in this way may be reached; but besides, as this arrangement renders it necessary for the besieger to make a circuitous route, it is also necessary, in order to guard against surprise, to interrupt the communication, and to cut off the counterscarp gallery towards the flanks or extremities of the front of attack by strong barricades, in order to isolate the part of it attacked. Without such precaution, it might happen that a violent explosion disclosing an opening in the counterscarp gallery, the besieger might enter it in force, spread right and left, and menace with a surprise the different portions of the Body of the Place.

Since, then, the counterscarp gallery does not always give to the besieged a sure route to reach the besieger's miner, when the latter is pushing his descent into the ditch, it is evident that there remains no other choice for the former than to cross the ditch, exposed to view from the besieger's lodgement, or else to employ the subterranean gallery already alluded to. When it is decided to construct such a communication, it is necessary to add a cesspool in the centre, and to arrange the floor of the gallery so as to drain into it the water that collects on its surface.

In case the galleries of mines cannot be drained into the ditch of the main work, recourse must be had to similar cesspools.

The dimensions of a gallery below the level of the ditch are the same as those of an ordinary gallery of communication, which is usually 6 feet high by 4 feet broad. But its masonry should be a little stronger than that of an ordinary gallery, because, having from its position but a slight covering of earth, it is liable to be crushed by
Plate IV. shells: it is therefore usual to give it a thickness of about 2 feet. Fig. 5 shews that grooves are made in the masonry immediately behind the cesspool; by the assistance of which barricades could more easily be made in the gallery, which would intercept all communication when it is decided finally to abandon the mining operations under the covered-way.

The names, dimensions, and positions of the various galleries having been now explained, it becomes necessary to describe the trace of a simple System of Defensive Mines, viz. that proposed by Dufour. (See Plates II. and III.)

If the fortification have ravelins with considerable saliency, as in the French Modern Bastion System, it will be inexpedient to place mines under the glacis opposite the salients of the bastion. For it results from the march of the attack, that the besieger gains possession of the ravelin previous to pushing forward his approaches on the glacis opposite the bastion : and therefore, as the passage of the main ditch is exposed to the view of the besieger's lodgements in the ravelin, the garrison could not communicate with the mines under the glacis of the bastion, excepting by a subterranean gallery below the ditch,—a mode which, as has been already stated, is often rendered impracticable from the difficulty of drainage, and is always insecure and uncertain. Besides, too, after the besieged have carried on for some time an active defensive subterranean warfare under the salient portions of their defences, it is not likely that the provision, either of powder or of men, would allow them to renew the struggle in the re-entering portions opposite the bastions.

The system of defensive mines here proposed must, therefore, be considered as applied only to the salient portions of the trace : but it must be understood, that where the besieger could crown the covered-way of the ravelin and of the bastion at the same time, a similar disposition of defensive mines must continue along the whole contour of the glacis. Making the pan-coupé of the salient place of arms 9 yards in length, lines *p q*, *q r*, *r s*, are drawn parallel to the crest of the glacis, and 60 yards from it. These lines give the limit of the extreme points of the galleries. Parallel to *q r*, and 72 yards from it, a gallery, *t r*, is made at right angles to the capital, and extending 20 yards on each side of it. Each end of this gallery is joined to the points *q* and *r* by two galleries, *q t*, *r v*, and the latter are produced to the counterscarp gallery. They are connected by a transverse gallery half-way between the lines *q r*, and *t v*, and parallel to them. A gallery on the capital extends from *q r* to the counterscarp gallery, and half-way between it and those terminating at *q* and *r*, are two others, extending only as far as the outer transverse one. The position of the galleries on each side is determined by placing the extreme points at equal distances of 26 yards apart, commencing from the points *q* and *r*. The first two are directed to the points *t* and *r*, and the remainder are parallel to them.

In this system the chambers of the mines and the floors of the galleries are in two different planes, which intersect at the extremities of the galleries. The plane containing the floors of the galleries, fig. 1, inclines towards the ditch, till it terminates in the counterscarp gallery : this inclination facilitates the drainage : the plane of the chambers of the mines inclines upwards, terminating at its intersection with a plane inclined to the horizon at an angle of 45°, and passing 8 yards from the crest of the glacis. The nearest mines to the fortress being at this intersection, will prevent the possibility of the besieged destroying the parapet of their own covered-way. The galleries are just near enough to insure the besieger's miner being heard, if he attempts to pass between them, but too far to ensure his being destroyed in them by the explosion of common mines. The position of the mine chambers is, therefore, reached by means of short branches, constructed for the purpose when the besieger's miner is heard at work. To facilitate this operation, openings *a*, *a*, *a*, *a*, fig. 1, large enough to commence branches from, are left in the revetment of the galleries, and parts even of the branches may be constructed permanently, in order to save time when the attack is made. At the junction of the galleries, the arrangements already described for increasing the ventilation and facilitating the communication would be made.

Plate IV.

PART V.—ATTACK AND DEFENCE OF A SYSTEM OF COUNTER-MINES.*

SECTION I.—OPERATIONS OF THE BESIEGER WHEN HE ARRIVES IN THE VICINITY OF COUNTERMINES—SUBTERRANEAN COMBATS BETWEEN THE RIVAL MINERS.

When the besieger arrives in the vicinity of the glacis of a countermined fortress, he is obliged to move more slowly, and dares not advance on the surface of the ground further than what he may be master of below. He then commences to excavate the earth, in order to try to discover the galleries of the besieged, and seize them, or else he endeavours to blow them in by firing mines. To accomplish this, in the middle of his third parallel he sinks shafts such as *a*, fig. 1, from 16 to 21 feet deep: he then pushes forward a gallery *d*, taking care to stop working at intervals, to listen if the enemy is coming to meet him.

Plate VI.

Often the besieged, especially when his galleries extend to a great distance, drives a branch almost under the third parallel, and fires one or more mines, such as *c*. The besieger under this supposition, ought to make a lodgement on the edge of the crater, as shewn in the figure, and sink a shaft (*b*) in his own lodgement. This shaft is not sunk from the bottom of the crater, because it would be the reservoir of all projectiles thrown from the place. Care must be taken, however, at the same time, to clear away the excavation caused by the globe of compression, in order to discover the direction of the branch which joins it, and which necessarily communicates with a main gallery. (See Plate VI.)

While the besieger is sinking the shaft *b*, he ought frequently to listen, for there is not a doubt that he is now in the vicinity of the mines of the besieged; and when he arrives at the depth of 18 or 20 feet, he commences a branch *e*, breaking out on that side where he imagines the enemy's gallery to be situated.

When the besieger finds himself sufficiently near to the Gallery of the Place, and is in danger of being forestalled, he hastens to dig a chamber at the extremity of his branch, in which he places a certain quantity of powder: he then tamps as fast as possible, and endeavours to fire his mine before the besieged can find time to establish one to destroy his work.

The besieged, on their side, directly they cease to hear the sound of the pickaxe, work with the greatest possible diligence, because they suppose from that instant their enemy is engaged in tamping their mine. If they have the good fortune to fall in with the mine, they endeavour to seize the powder, or else to saturate it by an inundation of water. If, on the contrary, they discover a part of the branch already excavated, they ought, without delay, to inundate it, in order to destroy the hose, and so prevent the powder from exploding. These artifices are made use of in like manner by the besieger.

It sometimes happens that two miners, who are working to meet each other, are only separated by a slight partition of earth. This is an occasion seized upon to give the 'camouflet,' which is performed in this manner: the most active of the two pierces a hole on the side of his enemy with borers of different diameter, in order to enlarge it gradually, and to give it a diameter of 6 inches: he digs this hole as deep as he can,—from 6 to 8 feet, for instance: he then introduces a large cartridge of the same size, containing from 12 to 20 lbs. of powder: he drives in this species of mine with a wooden plug, which he fixes and props up strongly with a piece of timber across the

* Compiled by Lieut., now Captain, De Butts, R.E.

branch: finally, he fires this little mine by means of a fuze which goes through the middle of the plug.

If the gallery of the enemy is but 4 or 5 feet from the head of this cartridge, he may be sure that it will be driven in by the explosion.

To produce the same effect, two or three shells, fixed together, are sometimes employed; but this method requires a great deal of care and attention, in order that one's own labour be not exposed to destruction.

In subterranean warfare, when two miners are working to meet each other, they take care to try the ground frequently with a borer, to find out exactly what distance they are off. In such a case, he who sees the end of his enemy's borer appearing, keeps a strict watch on the moment it is drawn back: he then introduces quickly into the hole it leaves a pistol loaded with ball, and fires it the moment he imagines the hole is clear.

This ought to be followed by three or four more; after which a probe is pushed into the opening, to clear it, and prevent the enemy from coming through on that side.

Vauban recommends the following articles to be provided in attacks of this description:

1st. A frame of wood like a shield, 3″ or 4″ thick, with a bolt in the middle to manage it with, and to place it against the hole perforated by the probe.

2ndly. Smoke balls: they are pushed in through the same hole when lighted, and care is taken to stop the orifice on one's own side, so that all the smoke goes into the enemy's gallery, by which means their miner is driven away for some time. During his absence the mine is charged and fired, which, by blowing in the gallery, prevents the return of the enemy. If the opening is wide enough, a shell or portfires to suffocate, or grenades may be introduced. The shell is to be preferred when it can be used, because it destroys the part of the gallery where it falls. When a thin partition of earth divides the combatants, a petard is used to blow it in.

Such are a great part of the artifices made use of by miners. To avoid them, the besieger should, as soon as he can, fire a mine to blow in the branches, and even the galleries of the besieged, if within reach. He is sure, by this means, of driving him away for some days. It is well known that the firing a mine shakes the ground to a considerable distance, so that if a gallery be within this limit, the gases of the powder penetrate and poison the air with such effect that no one can breathe it. This is not felt so much by the besieger, as he has more air, and is not obliged to use such long galleries.

Notwithstanding all the obstacles opposed to the advance of a besieger, he finally contrives to discover one of the main galleries of the besieged. Sometimes he arrives at it direct by mining: sometimes he gains access by means of the branch of the enemy which he meets in his road. In both cases there are means of attacking and defending a gallery, which will be given in the following section.

SECTION II.—STORMING OF THE GALLERIES—METHOD OF TURNING THE RETRENCHMENTS.

As soon as the besieger has discovered the gallery of the enemy, he ought, without delay, to attack it with vigour. For this purpose he takes care to provide himself with a small rolling mantlet, or shield, 3′ 2″ broad, and three feet high at the most. If this machine were larger, it could not pass through the branches. Covered by this mantlet, the miner advances, followed by men armed with grenades, presenting towards the besieged a machine filled with pistol barrels, which keep up an incessant

fire. He may also use grenades, or small shells, which are carried in a barrow, or other machine, behind which the miner covers himself. If by these different manœuvres he manages to penetrate to the retrenchments of the besieged, he endeavours to break it in, close with the enemy, and drive him back as far as possible by means of halberts, bayonets, and pistol-shots: after this, he barricades the abandoned gallery, or else makes a lodgement with sand-bags.

The besieged, on their side, have different methods of intrenching themselves in their galleries. When they are in brick-work, care is taken to divide them before-
Plate VI. hand, every 30 yards or so, by oak doors B and C (fig. 2). These doors are pierced with a large loophole, which is shut by a spring shutter. Inside and outside the door, blind branches (*d*, *d*) are made in the footings of the gallery, one to the right, the other on the left. The following is the object of this disposition.

Let us suppose the gallery B C to be an envelope gallery into which the enemy have penetrated by the branch A. The defenders then retire behind the doors B and C, which are closed in such a manner that they can be barricaded on both sides: the spring shutter is opened, and through the loophole are thrown small leather sacks filled with fireworks, and lighted with a lighted piece of tow; grenades are also thrown into the abandoned part of the gallery. The burning and explosion of the powder enclosed in these different projectiles cause such a smoke that the besieger cannot support it. By repeating this manœuvre, sufficient time is gained to bore, with a borer 6 or 7 inches in diameter, a hole in which from 24 to 30 lbs. of powder are placed, which is tamped properly. The explosion of these small mines (*f*, *f*,) will not fail to bring down the walls on the side of the besieger, and thus form in front of the gates a solid barrier, nearly inaccessible on account of the noxious vapours which generally exhale from earth and ruins impregnated with the smell of the powder.

If the besieger observes that the gallery has a sensible slope towards one of the doors, towards B, for example, he ought to close it up with sand-bags, as shown at D, in order to prevent any return of hostilities from that side: then, taking advantage of the slope to B, he will roll down howitzer shells, which, bursting near the lower gate will break it in. The besieged is thus obliged to retire 30 yards further. If the slope were sufficient for a strong man to roll the shells right up to the next gate, the besieged might thus be forced to abandon 80 or 100 yards of gallery without risk to the besieger, and to which the besieged could not return if care were taken to burn at intervals bags of powder.

It may, however, happen that the besieged are so strongly retrenched, and have so well known how to employ their means of defence, that the besieger is obliged to give
Plate VI. fig. 2. up the hope of penetrating by the branch A. In this case a great deal of confusion may be caused in the enemy's gallery, and all the barricades broken down by rolling against them one or two barrels of powder, having a lighted match attached. But if B C form part of an envelope, or of any other gallery of great length, and in a straight line, there is another mode of attacking and turning the retrenchments, both easy and expeditious; and which may be thus explained.

The besieging miner closes instantly the opening G with sand-bags, which he makes secure by filling up the spaces between the bags with clay, well rammed in. This done, he works without ceasing at the excavation of branches, 5 or 6 yards long, by the side of the foundations of the gallery. At the extremities, holes are driven with a borer from the top of the branches to the surface of the ground. The ends of the borer shew on the surface (of the ground) two points which will be of service in discovering the direction of the long gallery.

Let us suppose that by this means the position of the gallery A B (fig. 3) has been discovered: a flying sap is thrown up as far as B the following night, above

ground, and a shaft sunk on the gallery, 10 or 12 feet deep, in which a mine containing from 110 to 170 lbs. of powder is placed. The firing of this will infallibly break through the gallery, and by this speedy and certain manœuvre the besieged is forced to abandon a great part of his subterranean works.

There is another mode of attack which has not been used up to the present day, and which might nevertheless prove an infallible means of reducing, in a short time and with little danger, a system of defensive mines.

Let us suppose that a subterranean warfare has to be carried on in front of a fortress where there is a lake, a stream or other source of water : if the ground on which the attack is made is not much above the level of this water, there would be no difficulty in raising it by means of pumps, which might be worked by machines or by water-wheels, which are frequently met with by the side of running waters : the water thus raised might be poured in torrents into the galleries of the besieged directly a passage into them is made. By this means a great part of the defensive mines might be inundated to such an extent as would render them perfectly useless, or at least facilitate greatly the attack.

All the operations herein described are slow, and the success of some of them uncertain. To shorten the work, the besieger sometimes takes the opportunity of attacking the counterscarp with a body of men : for this purpose a great number of grenadiers, sappers and miners, are collected in the third parallel : these troops rush out before day-break, and force the barriers and palisades of the covered-way. Immediately after, a detachment of miners, supported by grenadiers, descend into the ditch and endeavour to penetrate the galleries of the besieged by the entrances, which are usually placed at the roundings of the counterscarp. They tear away the hoses of the mine already charged, try to pull down the frames of the galleries made of wood, and if they find a powder magazine of the enemy, they take one or two barrels, which they roll to the diverging points of the main galleries ; they place a match in them, and retire. The explosion of this powder, which is not strong enough to displace the earth above, causes a great disorder in the galleries, and is sufficient to prevent the besieged from re-entering there. Such a sudden attack, if it succeeds, may doubtless give a great deal of time to the besiegers. It must, however, be admitted that such an attack would be rash, and it must be premised that a weak or badly commanded garrison has to be dealt with.

Such was the method of attack and defence as recorded in the two previous sections, before the discoveries of Belidor on the effects of globes of compression.

SECTION III.—ATTACK OF DEFENSIVE MINES BY GLOBES OF COMPRESSION.—CALCULATION OF THE TIME REQUIRED TO REDUCE A SYSTEM OF MINES BY THIS MEANS OF ATTACK.

Belidor, reflecting on the effects ot powder, suspected with reason that the gases which result from its explosion ought to act in the same manner as all elastic fluids, which tend to displace obstacles in every direction opposed to their dilatation ; and as the volume of the gas is greater in proportion as the quantity of powder enclosed in the mine is more considerable, he concluded that under the same line of least resistance the craters ought to increase with the charges. Further on is given the result of the principal experiments by which he supported his theory, and on which he founded his method of attacking defensive mines.

Plate VII. The first experiment which he made was at La Fére in 1739. The mine N (figs. 3 and 4), having a line of least resistance of 10 feet, was placed 25 feet from the gallery C D, 30 feet from D E, and 35 from E F, and finally 42 feet from F C.

There was, besides, an inclined branch T, whose top, B, was 13 feet below the gallery. (See fig. 4, Plate VII.)

The mine was charged with 1200 lbs. of powder, and on firing it all the galleries were blown in, nearly in inverse ratio of their distance from the mine, as shewn in fig. 3. The branch which was under the mine was likewise driven in, and the diameter of the crater was found to be 45 feet.

This experiment, although conclusive in its results, did not convince some miners, which caused Belidor to propose new proofs. The French Government, feeling the importance of such a discovery, granted his request; and Count Argenson, then Minister of War, assembled Belidor and several officers of Artillery and Miners at Bizi in Normandy, where, in the grounds of the Duke of Belleisle, he caused the following experiment to be made.

Plate VII. In ground composed of soft sandy stone, four galleries, A, B, C, D, were built in masonry (figs. 5 and 6). The mine F, having a line of least resistance equal to 12 feet, was placed 24 feet from the gallery C, 30 from A, 36 from D, and 42 from B. Under the mine was a gallery lined with stout oak casing, 14 feet from the charge.

The charge was 3000 lbs. and the explosion produced a volcano nearly 150 feet high: the crater 66 feet in diameter and 17 in depth was perfectly circular.

The galleries D and A were broken in the whole of their length, except about 12 feet at one of the ends.

The gallery C was destroyed for the length of 45 feet, so that at one end 16 feet, and at the other 12 feet were left standing.

Finally, the gallery B was entirely broken in, with the exception of 12 feet at the end the most remote from the mine.

The gallery under the mine was found to be destroyed to the length of 12 feet, which leaves for the hypotenuse of the triangle E F Z (fig. 7) 38 feet. From this Belidor concluded that his globe would have destroyed a gallery 50 feet under the surface of the ground, which is the greatest depth at which defensive mines are ever placed.

The two preceding proofs were, without doubt, sufficient to establish the reality of the globe of compression, and shew how erroneous had been the opinions of former miners. They were further corroborated at Potsdam, in the presence of Frederic II., King of Prussia, by the engineer Le Febvre. As that officer carried on his operations in sand, he thought the L. L. R. should be increased, and therefore he made it 15 feet. He constructed three galleries, distant respectively from the mine 24, 32, and 42 feet: under the charge was a gallery distant from it 16 feet. All the galleries were 5 feet by 3 in the clear, and were lined with oak casing: 30 feet from the great mine a smaller one was constructed at the same depth. The charge of the first was 3000 lbs., and the following was the result.

The crater was 66 feet in diameter and 18 feet deep, free from rubbish, and perfectly smooth.

After such authenticated proof, there can be no doubt of the existence of the globe of compression. Practice and theory here coincided exactly: and instead of contesting results which did not admit of a doubt, it would have been far better, during Belidor's life, to have tried on the one hand to make them serviceable for the attack of defensive mines, and on the other to prevent their destructive effects.

However this may be, Belidor proposed to reach and blow in at a great distance, by means of his globes of compression, the subterranean works of the besieged: he observed truly, that the latter could not profit by the discovery; 1st, because it required too great a consumption of powder; 2ndly, without driving very long branches in front of his galleries, these would run the risk of being blown in; 3rdly, because the masses of earth thrown up by these explosions afforded too good cover to

a besieger. Thus the author of the discovery concluded that it would entirely be in favour of the besieger; and some time after, globes of compression served as a powerful auxiliary in opening the gates of Schweidnitz to Frederic the Great. In the works of Lefebvre may be seen an account of this memorable siege, during which the Prussians fired four globes of compression, the last of which blew in the counterscarp, driving the rubbish against the very revetment of the fortress, forming thereby a ramp as practicable as that produced by a breaching battery. It is to be regretted that Le Febvre, who directed the attack, and who ought to have visited the mines of the besieged after the surrender of the place, has not made us better acquainted with the detail of these new proofs. It would have been interesting to know at what distance from the mines the galleries were,—if they were ruptured, and for what length,—if the gases of the powder fired in the globes of compression penetrated into some galleries, and there spread so as to drive the besieged away. The silence preserved by him on these points leads to the supposition that he did not obtain from his mines all the effect he expected: and what makes this opinion still more probable is, that ten or twelve hours after the explosion of the two first globes, the besieged gave 'the camouflet' to the Prussian miner who was established in their craters.

This circumstance at the siege of Schweidnitz, recorded in the writings of Le Febvre himself, has renewed the old disputes on the discovery of Belidor; and some modern miners have gone so far as to deny the existence of the globe of compression. Notwithstanding the talents and reputation of these anti-globists, as Le Febvre called them, it must be confessed that the reasons which led them to this singular conclusion have not much foundation. Let us suppose that the gallery *a*, *b* (fig. 4), is blown in for the length of 30 feet or so, and that the besieger, having crowned the crater, sinks a shaft (C) a little to the right of his lodgement: there is no doubt, if the gallery be still sufficiently ventilated, that the besieger can, without loss of time, go to meet his under-ground foe, and give him the 'camouflet' after a lapse of some hours, as was done at the siege of Schweidnitz. All that we have a right to conclude from such an occurrence is, that the gases produced by the powder penetrated into the galleries only in small quantities.

Plate VI

Of all the opinions broached on this important process, those of Mouzé appear the most sound. This talented miner, observing that the galleries at Schweidnitz almost all presented their ends towards the besieger's mines, suspected that in this position they were less liable to injury from the effects of the powder, the explosion of which would, in a similar case, only overthrow some frames. This remark of Mouzé's was very judicious; and although not borne out by experience, he made it, as will be seen hereafter, one of the fundamental principles of his system of defensive mines.

Bousmard, the learned author of an 'Essai Général de Fortification,' does not concur in the opinions of the 'anti-globists.' He supposes, with reason, that the effects of globes of compression are sufficiently confirmed: he states that they are capable of destroying galleries at a distance from them equal to four times their line of least resistance; and combining these data with the time requisite for their construction, he also calculates the duration of a system of defensive mines in the following manner.

Let us imagine the glacis of a place to be mined to a distance of 240 feet from the crest of the covered-way, and suppose that the besieged either does not try to prevent the placing of the globes of compression, or that he fails in the attempt.

This is a supposition impossible to be admitted with reason, but may be assumed for a moment, the better to analyse the nature of the defence by which the lapse of time is estimated. This granted, the besieger, by the mere force of circumstances, finds himself arrested nearly a month on a glacis, such as has first been treated of.

If he breaks ground at 40 yards from the head of the most advanced gallery, by means of shafts 18 feet deep, their excavation will require twenty-four hours at least; and the radius of the crater of the globes of compression requiring to be 18 yards, each of the galleries (fig. 1) ought to be from 24 to 26 yards in length, in order that the parallel from which they break out may suffer no harm from the explosion, but not longer, or he will be heard. These shafts and galleries will consequently require from 4 to 4½ days' labour: the transport of powder,—the necessary time for loading the mine,—the placing the casing for the hose, and the tamping occupy at least 1½ day, which gives—

Plate VIII.

	Days.	
For the establishment of the first globes of compression, nearly	7	
For forming a lodgement to crown the crater of each of these globes	1	4½
The globes of compression of the second attack require:		
1st, Sinking shafts	1	
2nd, For branches 6 yards long, at the end of which each new globe is formed	1	
3rd, For the transport of powder, the excavation of the branches, and the tamping	1½	
Similarly, for the globes of the 3rd attack	4½	
,, ,, 4th ,,	4½	
,, ,, 5th ,,	4½	
Total	25 days,	

which may well be reckoned as 30,* including casualties and delays which always accompany a work of this nature.

But, adds Bousmard, how much more may the besieged retard this work, both by sorties, by spies, and by watching the transport of the wood for casing the shafts and galleries, as well as the heaps of earth which arise from their excavation? He may form on the parapets trench cavaliers opposite the most considerable heaps, and those of which the earth is of a fresher colour than the rest. By these means he may discover the spot where the miner is employed, before the latter gets to the bottom of the shaft.

The delays occasioned by 'camouflet' mines and the subterranean arrangements of the besieger cannot be estimated at less than a month, which gives a period of two months by which countermines prolong the defence of fortresses. It may be seen that the method proposed by Bousmard for the attack of defensive mines, by means of globes of compression, is the same as that followed by Le Febvre at the siege of Schweidnitz.

The Russians, in their war with the Turks in 1828, took advantage of this method against Silistria, not to destroy countermines, which the latter had not, but to open the counterscarps of fortresses they attacked, and drive the rubbish against the foot of the revetments, the upper part of which had previously been brought down by guns. This operation succeeded completely at the sieges of Choczim and Bender, where they thus managed to make practicable breaches. It would be very interesting to possess the details of these different operations. If a series of experiments, well authenticated, could be collected, and the circumstances of them combined, we might perhaps be able to arrive at satisfactory conclusions, and solve the following important problem:

* The time allowed seems excessive.—*Editor*.

Given the width and depth of the ditch of a work,—it is required to find the radi of explosion of an overcharged mine both vertically and horizontally, and the quantity of powder necessary to drive the ruins of the counterscarp against the opposite revetment, so as to form there a practicable ramp.

Although Belidor was the inventor of globes of compression, he did not suspect them of possessing this singular property; at least no trace of it is found in his works, and chance alone discovered it at the siege of Schweidnitz.

SECTION IV.—METHOD OF CONVERTING A GALLERY, OF WHICH THE BESIEGER MAY HAVE OBTAINED POSSESSION, INTO A TRENCH—METHOD FOUNDED ON THIS PRINCIPLE FOR THE ATTACK OF COUNTERMINES.

Not satisfied with having given to the besieger mines whose effects would be very extended, Belidor at the same time found out a simple way of converting into trenches the defensive galleries which had been seized. Supposing that an entrance has been effected into a gallery, he proposes placing at different intervals heaps of powder having a common hose among them. By firing them, the roof of the gallery is blown off, and if the charge has not been too considerable, a sort of ditch about 2 yards deep is formed on the surface of the ground, on the brink of which the earth raised by the explosion forms a parapet on either side.

In the experiments carried on at Bizi, miners penetrated into a listening gallery which was 40 yards in length, by means of the crater of a mine; at the same time they seized 24 yards of one gallery, and 12 of another. At the ends of these galleries retrenchments were made of sand-bags. The hose was then laid; ten barrels of powder in two heaps in the transverse gallery, sixteen in four lots in the longitudinal gallery, and as many more in the listening gallery, were laid respectively; the entrance through the crater was stopped up: all this took seven hours to complete.

The ground above the galleries was carried away by the firing of this charge, and the galleries were thus changed into trenches 8 yards wide by 2 or 3 yards deep.

Though these trials were renewed by Belidor himself, they are not yet sufficiently numerous to allow of rules being applied to them with certainty, suitable for different soils.

Belidor says that the heaps of powder ought generally to be 12 yards from centre to centre, and that for ordinary ground each lot or heap ought to contain three times as many barrels (each filled with 110 lbs. of powder) as there are yards in one-fourth the depth; that is to say, for a gallery 48 yards long, the floor of which is 6 yards under-ground, eighteen barrels, divided into four equal lots, would be required.

This rule, founded on experience, will suffice for any general applications that may be made of it; in it consists the method by which Belidor proposed to attack countermines, and by which he expected to reduce fortresses in a short time, by using their own galleries against them.

Plate IX. To give an idea of this, suppose *c* (fig. 1) to be the salient of an attacked front, *a b*, *a b*, and *a d*, three galleries of the besieged: Belidor excavates from his third parallel, in order to establish a globe of compression: this placed, he admits two different ways in which he might be opposed.

The besieged may first fire a mine to stop his work, and destroy the lodgement L: in this case Belidor crowns the crater, at the same time that a miner is endeavouring to discover the branch, break into it, and push on as far as the gallery of the besieged, which he attacks with all his strength, and endeavours to seize at any cost.

Supposing the besieged does not prevent the construction of the globe of compression, it is fired, blows in the nearest gallery, and drives him away. The earth is

then excavated before the air has been renewed in the enemy's gallery; they try to find the ruins of it, and enter and attack it vigorously, and retrenchments are made as in the former case.

In applying to galleries which have been seized the rule before given, Belidor converts them into trenches, and thus gains considerable cover, safe communications, and immense parallels, through which he proposes to lead the troops.

This method of attack is doubtless ingenious, and easy of application: it can be employed in many instances, and its effect would be decisive; it would not only destroy the galleries belonging to the besieged, but also the retrenchments and barricades that might be built by them.

It cannot, however, be expected that by this method exclusively a system of countermines can be destroyed. The besieger would in reality be obliged to renew frequently his attacks, so as to become master of the gallery; and it must be admitted that if the besieged knows how to make use of his position, the result of these combats would be often uncertain. Belidor has perhaps attached too much importance to his discovery, in applying it to all the systems of mines known in his time, the attack of which he has described, according to his new method, in his manuscript treatise on Subterranean Warfare.

This idea of taking places by means of their own mines appeared so engaging to him, that he proposed the building of galleries to places devoid of them, so as to convert them afterwards into trenches. As experience teaches us that a sapper can advance 160 yards above-ground in twenty-four hours, while a miner can scarcely build 4 yards of gallery in the same time, it is very doubtful whether this last idea of Belidor is within the limits of probability.

The 'History of Sieges' gives several examples analogous to those proposed by our author; and he himself affirms that in the war of 1701 the allies had recourse to a sort of covered sap, which they made use of with success at the sieges of Tournay and Bethune.

They advanced boldly, he says, between two horn-works, without running any risk from the tremendous fire kept up from the branches of these works, and arrived as far as the salient angle of the covered-way. They went under-ground to the depth of 2 or 3 yards by means of straight galleries 3 feet wide, 4 feet high, and 2 yards in length: when these small portions of galleries were completed, the earth above was blown away, then widened, and zig-zags excavated where necessary.

This example, although not very different from mining, may find applications in the attack of places liable to inundations, and which can only be approached by means of dykes or narrow causeways.

SECTION V.—ON THE FORMATION OF BREACHES BY MINES.

Since artillery has been so greatly augmented in armies, breaches have been made by guns in fortified places.

The method of making breaches by mines being slower, more dangerous, and less certain, has been abandoned in the present age. As, however, instances may occur in which an army without artillery finds itself obliged to carry an important post surrounded by a scarped wall, it is necessary to give some details on this subject.

When the besieger has established himself on the crest of the covered-way, and has effected a descent into the ditch, he pushes forward a sap to the foot of the revetment of the work he is attacking, supposing the ditch to be dry; if not, he ought to fill it up, and construct an epaulement on the side of the flank, as is done at the attack of places. He then places against the revetment the planks *c* (fig. 1), Plate VII.

2 or 3 yards long, 1 foot wide, and 4 inches thick : these are covered with tin, to resist fire : they are made to lean against the wall, leaving sufficient room for two miners to rest conveniently, and work at their ease. Finally, the besieger covers them with raw hides, and forms an epaulement with sand-bags, to protect the men from the fire of the collateral works.

The miners, under cover of the planks, then work to break through the revetment, and bury themselves in the wall as fast as possible. The entrance, or 'eye of the mine,' as it is technically called, ought to be a foot above the level of the water,—supposing that the enemy have no means of raising it by inundating the ditch : without this precaution, there is a risk of the work being inundated ; and, as a general rule, the miner should always commence work one foot above the level of highest water.

When it is possible to erect a battery of one or two guns on the covered-way, to cover the miner, the opportunity should not be lost. In aiming constantly at the same spot, a hole 1 or 2 yards deep is soon opened, into which the miner gets, and is soon under cover from the fire of artillery or musketry from the flanks, as well as shells and grenades, which are rolled down upon him from the top of the rampart. He has then only the sorties and the mines of the besieged to fear.

The miner ought to enter the revetment by a horizonal gallery at right angles to the direction of the face of the work which he is entering : this little gallery is $3\frac{1}{2}$ feet high by $2\frac{1}{2}$ feet broad. When he gets to the earth of the rampart, he drives two galleries, right and left, which are directed along the inner side of the revetment wall, and which are 2 feet 6 inches high and 2 feet wide ; their length varies according to the thickness of the wall, and the mines placed at their ends should be so regulated that their lines of least resistance may meet at a point.

At the end of the branches, the chambers of the mines are dug so that one-half of them is in the masonry of the wall. Vauban states that this is the best method of obtaining the greatest effect : when mines can be established in the counterforts, care is taken to do so. A twofold advantage is gained by this ; the powder acts with more certainty on the outside of the revetment, at the same time that the counterforts destroyed completely leave the earth to support its own weight.

When the chambers of the mine are completed, the powder is brought up in sand-bags ; they are then loaded and tamped. The firing should be simultaneous, in order that the explosion of the mines taking place together may produce the more considerable results.

Plate VII. Fig. 2 shews instances of mines thus bored in the thickness of the rampart : it is taken from a treatise by Vauban. Other mines, besides those behind the revetment, are there shewn in the earth, to render more certain the overthrow of the revetments, and to facilitate the ascent of the breach.

It may happen that behind the revetment where the mine is commenced, a gallery *a* or *b* (fig. 1) may exist. In this case the besieged can annoy his enemy greatly, and retard considerably the placing of the mines. The besieger ought then to try to break into the gallery, by means of a petard, when there is before him only a slight partition of masonry. When he once effects an entrance, grenades and fire-balls should be thrown in, to drive away the enemy for at least some time : he then widens the opening, and prepares to attack the gallery by storm. If he drives the enemy out altogether, or partly, he retrenches himself, and then commences establishing a mine.

When the gallery in the wall of the escarp is sufficiently retired towards the interior of the work, the besieger may then save a great deal of time and trouble by sacrificing a proportionate quantity of powder. It will only be necessary to form a breach, to close the two ends of the gallery (if open at two ends) by sand-bags and logs of wood

laid across, and to collect in the space between a great quantity of powder in heaps. The explosion will bring down the whole of the face of the work. Some proofs of this expeditious mode of proceeding have been made.

In the preceding it has been supposed that the wall required to be opened has earth at the back; but it may happen that a breach is required to be made in a castle situated in a defile where cannon cannot be transported.

Plate VII. In this case, suppose *a a*, fig. 2, to be a wall first required to be opened for a mine; the thickness must be ascertained as nearly as possible; a gallery *b* is then commenced at the foot of the wall, which is driven to the middle of it; returns are made at right angles to this gallery, and at the end of them are placed the mines *c c*: the explosion of these taking place simultaneously will throw down a greater portion of the wall.

This supposes the wall to be 3 or 4 yards thick; but if it be only 2 yards or less, it will be necessary to establish one or more mines under the foundation, supposing the ditch to be dry, taking care to place them in the middle of the whole width. To overthrow a wall only 2 or 3 feet thick, it is sufficient to place one or more barrels of powder against it.

APPENDIX I.

*Observations upon Mine Frames for Field Service.**

When the mining practice commenced at Chatham, in the year 1812, the system which was then adopted was not that now in use, called 'chassis à la Hollandaise,' but the earth of the galleries was supported by means of a frame of peculiar construction, admirably suited to the purpose, resembling in some respects a common door-frame.

This frame was composed of a capsill of from 4 to 6 inches in depth (according to the size of the gallery) and 4 inches in width; of stanchions 4″ × 4″ and of groundsills 4″ × 2″; and they were put together without nails or screws, or other fastenings, and were not subject to derangement.

The frames were placed at intervals of from 3 to 4 feet apart, according to the nature of the soil, and formed the support of a series of planking, 9 inches wide and 2 inches thick, called the 'top sheeting,' which was lodged upon the capsills, and of other planks, 9 inches wide and 1½ inch thick, which supported the sides of the gallery, and were called the 'side sheeting.'

On the bottom of the gallery, the groundsills alone rested, and were let into the floor, so as to be flush with the surface of the ground.

Some years later, for some reason which I have never understood, this system (which was copied by some of the continental nations) was abandoned by us, and recourse was had to the system called the 'chassis à la Hollandaise.'

This is a case composed of 4 pieces of plank, of from 1½ to 2 or 2½ inches in thickness (according to the size of the gallery), and the width depends upon that of the planks which can be obtained.

The form of this case is rectangular, and both the capsill and groundsill have two notches at each end, while at each end of both the stanchions, there are tenons corresponding to those notches.

Each of the stanchions is hollowed out on both edges near the middle of its length, to admit of its being more easily handled by the miner, and for pickets being driven through the opening thus formed into the sides of the gallery, to keep the stanchions more steadily fixed when used for the support of ascending or descending mines.

In the practice at Chatham it is found necessary to cut away more of the head of

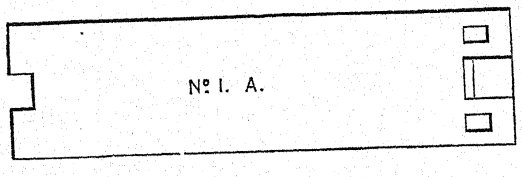
* By M.-Gen. Sir Frederic Smith, R.E.

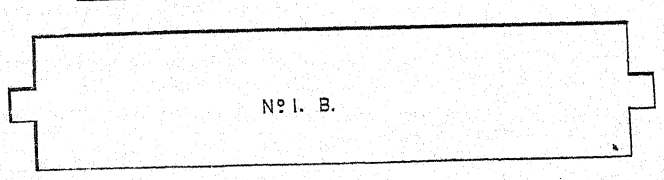
the gallery than the mere height for the case when placed, to allow of its clearing the top of the tenon in the act of placing it, after which it is dropped into its place; therefore an interval is obliged to be left between the upper surface of the capsill and the earthen roof of the gallery, equal in depth to the height of the tenon.

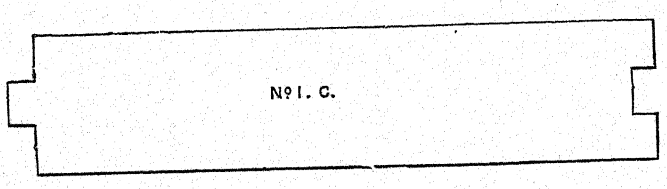
It was found that this gave the opportunity for a settlement of the ground; and this induced Serjeant-Major Jones * to suggest an alteration of the frame, which, to a certain extent, is an improvement.

It will be seen, from what has been stated above, that a capsill will answer the purpose of a groundsill, and that the stanchions are suitable to either side of the gallery.

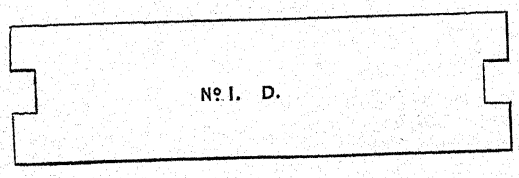
In Serjeant-Major Jones's proposition, one end of the groundsill had a notch cut in it, to receive the tenon of one of its stanchions, that stanchion having two tenons. The other end of the groundsill has a cleat nailed upon the surface, in a position corresponding with that of the notch at the other end. The stanchion for this side has also a notch cut to fit over this cleat, and at the other end of the stanchion there is a tenon, like that on the opposite side of the case. The capsill has a notch at either end, to receive the corresponding tenon.







In placing this case the groundsill is first bedded, then the left stanchion is placed perpendicular to the groundsill, one of the tenons being inserted into the notch. The



capsill is then placed so that its left notch receives the upper tenon of the left stanchion, and then the tenon of the right stanchion is partially inserted into the corresponding notch of the capsill; but this stanchion is inclined, with its heel approximating to

* Late Quarter-Master, Royal Engineers, now Captain half-pay.

that of the stanchion previously fixed, and is then gradually slid along the surface of the groundsill till its notch passes over the cleat, when two pickets are driven through mortise-holes on either side of the cleat, to keep the stanchion from being forced out of its proper position.

This system gives a facility not only in placing the frames, but in removing them for the purpose of tamping a gallery, which is often a difficult operation, if there be much pressure of ground on the capsill in the old system.

The disadvantage of this plan is, that the stanchions are not of universal application, being of different form; the one having two tenons, and the other only one.

The groundsill will answer for the capsill, if both are supplied; but if by any want of arrangement either should be deficient, a superabundant quantity of the other will not supply its place.

A consideration of Serjeant-Major Jones's proposal led to a simplification of the mine case, which may be described as follows.

In the first place, the groundsill and capsill are identical in form. Each has a rebate at both ends, of the same width as the thickness of the stanchions, and running across the whole width of the plank, its depth being half an inch. The stanchions are mere rectangular pieces of board, without any workmanship whatever upon them, excepting an auger-hole through the centre of each, for the purpose of picketing them to the sides of the gallery.

As in the former instance, the groundsill is first lodged in its position; then one of the stanchions, with its end resting on the flat surface of the rebate; afterwards the capsill is placed with the rebate at one end resting upon the upper edge of the stanchion; and lastly, the opposite stanchion has its upper end placed in contact with the corresponding rebate of the capsill, whilst the lower extremity or heel of the stanchion rests upon the middle of the groundsill, and is gradually moved along its surface, until it drops into the rebate at its own end.

So far as simplicity of construction and the more general application of its parts are concerned, this case appears to be an improvement upon that of Serjeant-Major Jones for galleries and branches, but it is not, like his, applicable to shafts.

With the simple case last described, the excavation will be very little more than that required for Serjeant-Major Jones's case,—merely the extra half-inch at one side, to allow of the depth of the rebate; but practically this is of no importance.

In the mining operations of the year 1847, at Chatham, the cases of all three descriptions were in common use; and as there was an abundance of each at hand, with a store suitably placed with reference to the work, no inconvenience or confusion arose from the misplacing of the several parts employed.

Any practical miner, capable of using a saw, could make the more simple case without difficulty; and it is obvious, that in preparing these cases there is a considerable saving of time.

For preparing this case, the only tools required are the saw and the auger: and in the other, the following addditional tools would be necessary, viz. a gimlet, a hammer, a chisel, and a mallet, with nails.

In very loose soil, it is found difficult to drive a gallery supported by either description of case that has been described; whereas there is scarcely any soil (but a running sand) in which the original frame and planking of 1812 could not be used.

In the old system in question, the planks were inserted over the heads of the capsills, and behind the sides of the stanchions, and were driven gradually forward in advance of the workmen, by means of chases cut out with a push-pick; false frames being occasionally used, to support the more advanced ends of the planks. I believe, on the whole, that the old plan was the best. F. S.

APPENDIX II.

*Record of various Experiments made in Mining Operations.** (See p. 380.)

No.	Lines of least resistance, in English feet.	Radii of crater, in feet.	Charge, in English pounds.	Horizontal radii of Rupture, in English feet.	Vertical radii of Rupture, in English feet.	Places and Authorities.
1	13·0	13·0	162	...	...	Tournai, 1686. Gillot.
2	13·0	13·0	216	10	12	Tournai, 1689. R. E. Papers, vol. ii.
3	10·0	11·0	139	17·6	14	Chatham, 1834 and 1835.
4	15·0	15·0	253	19	15	
5	15·0	15·0	253	15	11	
6	11·0	20·0	(280)	22	...	(anomalous) Coblenz, 1856.
7	14·8	not stated	280	15		
8	27·1	none	324	27	27	Tournai, 1686.
8a	13·0	16·3	324			
9	25·0	none	432	30	...	Tournai, 1689.
10	19·6	19·6	490			
10a	18·5	21·0	540			
11	10·5	21·6	560	32	...	Coblenz, 1856.
12	12·0	17·0	560	25		
13	25·0	none	650	30	...	Tournai, 1689.
14	22·0	21·8	720			
15	16·3	22·0	1058	...		La Fère, 1732. Belidor.
16	11·0	24·0	1296	(45)	...	(anomalous) La Fère, 1732. Belidor, Gillot.
17	27·0	27·0	1500			
18	31·5	31·5	2484	...	...	Tournai, 1689.
19	12·5	32·0	2592	...	...	Schweidnitz, 1762.
20	16·3	29·0	2592	...	...	La Fère, 1732. Belidor.
21	21·8	32·6	2752	...	...	Schweidnitz, 1762 . . Mouzé.
22	16·3	...	3240	...	...	Potsdam, 1752. Mouzé.
23	13·0	35·9	3240	52	25	Bizi, 1753. Belidor, Gillot.
24	37·0	37·0	3828	60	...	Tournai, 1689.
25	16·3	38·0	3828	...	...	La Fère, 1732. Belidor.
26	13·0	39·0	3828	...	...	... ... Gumpertz and Le Brun.
26a	20·6	32·0	3888	...	...	Schweidnitz.
27	15·9	34·8	4320	70	...	Verdun, 1759. Tournai, 1689.
28	37·11	37·11	4320			Less depth and less crater than No. 28.
29	16·3	42·3	5405	...	...	Schweidnitz, 1762.
29a			5405			
30	44·5	44·5	7136	...	...	Tournai, 1689.

As regards charges placed at depths greater than 10 feet, we observe that equal charges produce equal craters, though at different depths; and we are led to the con-

* Collated by Lieut.-Colonel Bainbrigge, R.E.

clusions that $\frac{1}{11}$th rad.^{3} will in common soil give the charge; and that a formula not dependent on the depth should be used for determining the probable horizontal radii of rupture; for instance, add 1500 to the charge in lbs., and divide the sum by 90, to get the horizontal radii of rupture in feet.

APPENDIX III.

Memoir on the Object of the Breaching Experiment carried on at Bapaume in 1847; *and on the present State of the Science of Military Mining.**

1. All experiments of breaching by mines should be directed to two principal points:

First, on the best mode of attaching the miner, and of arriving in the shortest time at the proposed chambers of the mine.

Secondly, on the position of those chambers, and of the charge proper for the mines.

Mode of attaching the Miner, and of arriving in the quickest Time at the Chamber.

2. Vauban attached the miner about 2 feet above the bottom of the ditch; he regarded the operation as a difficult and dangerous one, and recommended that a gun should be brought into the covered-way, or to the foot of the descent, and a few rounds fired from it, to indent the wall sufficiently to afford some cover to the miner, when attached. He thought this mode of affording cover to the miner much preferable to placing planks for this purpose against the escarp, forming a sort of lean-to roof.

3. The same effect has been attempted to be accomplished by firing wall-pieces against the escarp, but without success.

4. A bag of powder placed against the wall, and covered with sand-bags, has also been proposed; but sufficient experiments have not yet been made to decide whether this mode of operating, in order to obtain cover for the miner when attached, would be always successful.

5. The Committee of Fortification recommend that the miner should pass under the wall in sinking a small shaft and driving a gallery under the foundation. This suggestion would only be practicable in situations where neither rock nor water would impede the miner.

6. The Committee of Fortification also recommend that miners should be attached to the escarp at two points, separated by intervals of about 10 feet.

7. If the ground is not difficult to excavate, it is better only to sink so deep as to allow the gallery just to pass under the foundation of the escarp; the foundation itself forming the top of the gallery.

Positions of the Chambers of the Mines and their Charge.

8. All Engineers are of opinion, that in order to make a breach, it is better to put too much powder than too little; at the same time it is desirable not to project the débris too far. It is also necessary that the earth of the rampart should, by the effect of the explosion, be so disposed after the fall of the revetment, as to form an accessible ramp: it is universally acknowledged, that making a breach by a mine must not be considered as a simple demolition of the escarp.

9. Vauban retired the chamber of the mine from the face of the escarp at a distance equal to one-half or one-third of its height, in order to prevent the line of least resistance being vertical. This rule placed the chamber of the mines near the tails of the

Plate X figs. 1 and 2.

* Translated by the late Lieut.-Col. J. Williams, R.E., from an unpublished Memoir of the Frenc Committee of Fortification.

counterforts. He computed the charge with the line of least resistance measured from the chamber to the face of the wall, as for ordinary earth, allowing one-fifth to one-third in excess, to prevent the charge from being too small.

Fig. 3. 10. Cormontaigne placed the chambers of the mines in the same vertical plane as the tail of the counterforts, separated from each other by central intervals of 30 feet; each chamber therefore did not necessarily find itself behind a counterfort; his system was particularly applicable to breaching a salient: he verified the rule laid down by Vauban, viz. that the distance of the charge from the face of the revetment should be equal to about one-third of the height of the escarp.

Principles upon which the Charges of the Mines were determined in the Demolition of the Ramparts of Vienna; par le Chef de Bataillon Constantine.

11. 21·594 lbs. (20 lbs.)* of powder are required in a common mine to raise 9·68 cubic yards (a cubic toise) of masonry. The following table is computed upon this datum.

H.	c.†	H.	c.	H.	c.
(6 feet.	50lbs.)	(11 feet.	230)	(16 feet.	700)
7 ,,	75	12 ,,	300	17 ,,	830
8 ,,	95	13 ,,	370	18 ,,	990
9 ,,	125	14 ,,	465	19 ,,	1160
10 ,,	170	15 ,,	570	20 ,,	1350

The volume raised by the explosion was taken at $\frac{11}{8}$ H³. The craters were tangent to each other; where there was an escarp gallery, the line of least resistance was the distance from this gallery to the face of the escarp. The number of mines necessary was first determined from the assumption that they were to be separated by two-lined intervals; then one-half above the charge computed in the ordinary way was added, in order to allow for the powder being placed unconfined in the gallery, and for the suppression of the tamping.

When the quantity of powder has been calculated, it should not be spread over the floor of the gallery, but placed in heaps: more certain effects are obtained by this arrangement.

In order to secure the complete destruction of the escarp, the charge should be above the foundations, at a height at least equal to the line of least resistance: this position prevents the expansion power of the powder from acting unnecessarily deep.

Bastion Elend, fig. 14.—The total charge of the mines was 7558 lbs. (7000): they were fired simultaneously: the revetment was completely overthrown, the masonry broken into small pieces, and the breach easy of access.

Bastion de Molech, fig. 15.—According to the Table, a mine with a line of least resistance of 14 feet (13) should be charged with 399·5 lbs. (370) of powder. On a length therefore of 153½ yards (72 toises), sixteen mines, charged altogether with 6392 lbs. (5920), will be necessary.

Another portion of the escarp was 85 yards (40 toises) long, with a line of least resistance of 15 feet (14), requiring as the united amount of the charges 4021 lbs. (3720), making altogether an expenditure of 10,408 lbs. (9640) of powder. One-half of this amount was added as a measure of precaution, giving a total of 15,612 lbs. (14,000) of powder. The tamping consisted of the gallery being tightly occupied in four places by pieces of split wood about 2½ feet long. The powder was disposed in heaps of 1000 lbs. along the faces, and of 2000 lbs. at the salients and shoulders. The escarp was quite destroyed: but little noise accompanied the explosion, nor did

* The figures placed between parentheses express the French weights and measures.

† H is the line of least resistance in French feet; c, the charge in French lbs.

it occasion pieces of masonry to be projected to any distance. The earth of the rampart disposed itself, after the fall of the wall, as in fig. 14. The tamping formed of wood had been moved bodily, and with much violence, along the gallery.

Plate XIV.

Plate XV.

Bastion de Burg, fig. 20.—The bastion was destroyed by placing the charges in an escarp gallery. This gallery passed through the counterforts: where it became narrowed, between each counterfort, a chimney or flue led the whole height of the escarp, and communicated with the air. The escarp gallery extended along the faces and flanks of the bastion for a distance of 320 yards (150 toises). Each mine required to be charged with 1069 lbs. (990) of powder, and twenty-five mines were required to destroy the whole length. The charges, therefore, amounted altogether to 26,722 lbs. (24,750), which, with the addition of one-half to insure full effect, made a total of 39,949 lbs. (37,000).

But in consequence of the great length of the gallery, causing a corresponding augmentation of powder, the mines were only loaded with 35,630 lbs. (33,000).

The entrances into the galleries were tamped with wood and earth: 5938 lbs. (5500) were placed at the salient; 4859 lbs. (4500) at the left shoulder, and 3779 lbs. (3500) at the right shoulder; the charge at the latter point being diminished from the apprehension of damaging the bridge which stood in its vicinity. Three intermediate heaps, each amounting to 2267 lbs. (2100), were placed between the salient and each shoulder. In the centre of the right flank, a mine charged with 2100 lbs. was placed, and another of 2375 lbs. (2200) in the centre of the left flank: 2700 lbs. (2500) were employed in communicating by a train the fire along the whole extent of the demolition.

On the right face, the staves of the powder barrels were broken on one side when placed in the chamber. The same arrangement was made on the left face; the barrels were staved on one side, and the powder was afterwards placed in heaps. Notwithstanding a proper arrangement had been made to secure simultaneous explosions, the mines on the left face were the first to ignite. The report of the explosion was heavy, resembling that of common mines in ordinary earth with a line of least resistance of 20 feet. But few fragments of masonry were projected vertically, but some of the wood which had been employed in tamping the chimney was thrown 200 yards (metres) from the escarp. The bastion was in ruins, with an easy access from the ditch into its interior, along the whole extent of its contour. The salient angle was not, however, thrown completely down; the angle of the right shoulder also remained standing. On the right face some fragments of the counterforts, situated between the charges, presented inaccessible portions. On the left face, the greater part of the masonry, after having been pushed forward 16 metres, fell, with its lines of fracture converging towards the charge, while the disposition of these fissures on the right face took an opposite direction.

Curtain 7, 8 (no figure given).—The curtain had a relief of 47 feet (14·6 metres). Twenty-two shafts, 25 feet 4 inches (7·80 metres) apart, were sunk in the parapet to a depth of 35 feet 10 inches (11·30 metres): a small branch was driven out from their bottom till it reached the masonry, in which the powder was lodged so as to have a line of least resistance of 12 feet 8 inches (3·90 metres). Each mine was loaded with 287 lbs. (130 kilo.) of powder. The small branches were tamped with turf and wood, the shaft with earth well rammed at every 3 feet. No precaution was taken to fire the mines simultaneously; the demolition of the curtain was complete, without a wide dispersion of fragments, and without report or violent shocks.

Cavalier 7.—The walls were more than 20 feet thick; branches were driven 12 feet into the masonry, measured from the face of the escarp. Each mine was loaded with 215 lbs. (200) of powder instead of 324 lbs. (300); arrangements were

made by the disposition of the hose to effect the simultaneous explosions of the mines. The effect of the explosion was to throw down the face of the wall for a thickness of 2 feet, the remainder of the masonry remaining in its place. The tamping of the branches was blown out. In driving the branches through the masonry, the former were never advanced quicker than 13 feet (4 metres) in twenty-four hours, with a working party of six miners.

In shafts which did not require lining, the sinking progressed at the rate of 1 foot (0·32 metre) per hour; branches in brick-work, with a working party of four miners, advanced 3·3 feet (1 metre) daily, very regularly; in stone-work, as bastion No. 7, this rate was reduced to 1 foot (0·32 metre).

Shafts with lining were paid for at the rate of 3 francs per running metre; if not lined, one-half that price was paid: branches driven through masonry, at 6 francs per metre run. The miner not employed at task-work was paid 0·75 franc daily; sapper 0·70; other soldiers 0·50 each.

These prices, however, varied towards the conclusion of the demolitions; task-work was paid for at double the above prices, but it was found that the increased price did not accelerate the progress of the work. The tamping had been completed in nine hours; but with a strong working party, eight men were usually employed in tamping a shaft with a gallery leading from it: if, however, only a shaft, the number of men was reduced to four; half were sappers and half miners.

Demolition of Ulm in 1806, *under the Direction of the Commandant Breuille.*

12. The masonry was assumed to require 2·7 lbs. (1·25 kilo.) of powder per 1·308 cubic yard (cubic metre), and 1·65 lbs. (0·75 kilo.) for the same volume of earth.

Plate XIV. The shaft No. 1, fig. 16, was made in eight hours; the chamber in half an hour: loading occupied a quarter of an hour, the charge being 80 lbs. (36 kilo.) Two planks jammed in the shaft, and 1 foot (0·09 metre) thick formed the only tamping. The explosion was accompanied with a loud noise; the counterscarp thrown down for a length of 23 feet (7 metres); the débris from the breach was thrown more than 26 feet (8 metres).

Shaft No. 2, fig. 18, sunk 3·3 feet (1 metre) in rear of the masonry, had a line of least resistance of 8·8 feet (2·70 metres): the charge was similar to that of shaft No. 7; the crater was formed on the surface of the ground, cracking, however, the wall and the neighbouring ground: 80 lbs. (36 kilo.) of powder were subsequently placed behind the wall, the tamping made good, and a breach, 9 metres in length, was formed by the explosion.

Shaft No. 4 was disposed as No. 2, but charged with 159 lbs. (72 kilo.) of powder: 30 feet (9 metres) running of counterscarp were overthrown.

Shaft No. 5 was charged as No. 4, but the chamber was placed 6·5 feet (2 metres) from the face of the wall. The charge computed for ordinary earth would have been 200 lbs. (75 kilo.) The explosion produced a crater the diameter of which was 14 feet (4·40 metres). The wall was thrown a little from the vertical, and was cracked for a length of about 13 feet (4 metres): the explosion was very loud; pieces of the top frame were thrown to a distance of 218 yards (200 metres).

Shaft No. 6.—The mine was placed 5 feet (1·50 metre) from the face of the wall, and loaded with 192 lbs. (87 kilo.); the tamping was not made in the usual manner with earth, but formed with wooden struts jammed across the shaft. A crater was produced of 16 feet (5 metres) in diameter and 3·3 feet (1 metre) in depth; the wall was pushed forward, opposite the chamber, for a distance equal to 10 inches (0·25 metre).

The report of the explosion was extraordinary; a piece of wood was projected 874 yards (800 metres).

Shaft No. 7 was 16 feet (5 metres) deep, and placed 6·5 feet (2 metres) from the interior face of the revetment: the charge was 343 lbs. (128 kilo.), disposed as in the preceding experiment. The wall was overthrown for an extent of 45 feet (14 metres), forming a practicable breach for the distance of 30 feet (9 metres) on one side of the former breach, and 16 feet (5 metres) on the other. The mine was surcharged towards the masonry.

13. *At the periodical inspection at Montpellier, in* 1833, *M. le General Valazé* directed a counterscarp to be overthrown, with a view of obtaining cover, amidst the débris, to cross the ditch, and gain the breach. This project was not considered a very advantageous one; but it will be examined here, in consequence of its bearing with mining operations. The counterscarp (see fig. 10) was 21 feet (6·4 metres) high, 6·6 feet (2 metres) thick at the base, composed of bad masonry; a shaft was sunk 16·3 feet (5 metres) deep, and the chamber of the mine placed in a small return 8·4 feet (2·60 metres) from the face of the wall. The charge was 375 lbs. (170 kilo.), that is to say, an ordinary charge, computed for a line of least resistance of 16·3 feet (5 metres); but admitting that masonry is double the weight of ordinary earth, this charge is a surcharged one on the side of the masonry. The explosion produced a crater 16·3 feet (5 metres) in radius in the covered way, and one of 23 feet (7 metres) on the side of the masonry. To form a crater of 23 feet (7 metres) radius in common earth, with a base of least resistance of 8·4 feet (2·60 metres), would have given $n = \frac{7}{2{\cdot}60} = 2{\cdot}68$ (8·4 feet): the side of the powder-box would therefore have been $B = \frac{T}{8{\cdot}5}(1{\cdot}05 - 0{\cdot}05\,n) = \frac{T}{8{\cdot}5}(1{\cdot}05 - 0{\cdot}05 \times 2{\cdot}68) = 0{\cdot}82\,(0{\cdot}916) = 0{\cdot}745$ metre (2·43 feet), corresponding to 827 lbs. (375 kilo.), which is more than double the charge of 375 lbs. (170 kilo.) employed in making the crater in vertical masonry.

Plate XII.

See formula 5, page 422.

This experiment points out two facts equally important to note: 1st, That for vertical masonry to produce a given crater, requires only half of the charge required for producing the same crater in common earth. 2nd, That notwithstanding the facility with which the masonry has given place in a vertical direction to the explosion of the mine, the crater in the covered-way has preserved the same diameter as it would have done had it been exploded under common earth.

Plate XII. figs. 9, 22 and 23.

14. Among the experiments made at Metz, in 1834, a counterscarp was overthrown by two mines. The mines were placed in the earth; the line of least resistance was 7·8 feet (2·40 metres) in the direction of the masonry, and 13·2 feet (3·06 metres) to the surface of the ground. The charge, in earth, for a line of least resistance of 7·8 feet (2·40 metres) is 53·6 lbs. (20 kilo.): the actual charge used in this experiment was 132 lbs. (60 kilo.); first, to allow for the masonry, the coefficient of which was taken at 2; and because the charge, computed as above, for earth, was considered as small. The radius of the crater was nearly 13 feet (4 metres), corresponding to a charge of 222 lbs. (83 kilo.) in common earth: the vertical masonry had not resisted more than earth; but, on the other hand, must be remarked the wide interval of the mines, 47 feet (14·5 metres), and the adhesion of the masonry within itself, shewing that if the craters had overlapped, so as to have made $n = 3$ at a minimum, then the charge for common earth would have been 122 lbs. (55·7 kilo.) in place of 132 lbs. (60 kilo.)

Plate XV.

Plate XI. figs. 5 and 6.

15. At the siege of Antwerp, in 1832, the escarp of the lunette St. Laurent was found to have the following construction. It was built 'en décharge,' the arches having a span of 8 feet (2·50 metres), resting on counterforts 3 feet (1 metre) broad, and 14 feet (3·40 metres) long. The mines were separated by intervals of 19·8 feet (6 metres); the two extreme ones were placed immediately behind the counterforts,

the intermediate one a little in rear of this alignment. The charge which, computed by Vauban's rule, would have been (62·30 kilo. + $\frac{1}{3}$ (62·30) = 84 kilo.) 225 lbs., or computed by the formula deduced from the experiments made at Metz in 1834, would have been 375 lbs. (140 kilo.), was increased to 1103 lbs. (500 kilo.) per mine, from an assumption that the revetment, being strengthened with counter-arches, would offer greater resistance. The result was enormous, although the intermediate mine did not explode for ten minutes after the others. A breach was made on the two faces of the lunette, and the bridge of fascines across the ditch partly destroyed. Colonel Vaillant, however, succeeded in restoring the bridge and crowning the breach. A Dutch sentinel posted on the terreplein above did not know that a breach had been made, and did not leave the salient of the lunette.

Plate XI fig. 8. 16. In the experiments at Metz, in 1834, an attack by mines was made on four counterforts; the charges of the extreme mines were placed in the counterforts themselves, and amounted to 463 lbs. (210 kilo.); the intervening mines were placed at the roots of the counterforts, and loaded with 200 lbs. (90 kilo.); a mine charged with 220 lbs. (100 kilo.) was also placed in rear; the co-efficient of masonry was taken at 2, and in order not to disperse the splinters too widely, $\frac{3}{4}$ths only were taken: the charge was therefore $\frac{3}{4}$ of 2 C, or $\frac{3}{2}$ C = 210 kilo. (463 lbs.), the half more than the charge for common earth. The explosion made a practicable breach, easy of access; the extent of wall breached was 98 feet (30 metres) in place of 66 feet (20 metres); the radius of the crater of the extreme mines was 19·8 feet (6 metres), with a line of least resistance of 15 feet (4·50 metres).

17. From an examination of the general abstract of the experiments made at Metz in 1834, drawn up by the Commandant Balmas in 1837, he concludes that in every case the mines ought to have been placed behind a counterfort.

18. General Guilleman, at the conclusion of a memoir on the demolition of counterscarps, says, "I have remarked besides, in a number of demolitions made by mines placed in the earth behind revetments, that if there was a depth of earth above the charge equal to the line of resistance on the side of the ditch, the demolition rarely failed; although the specific gravity and tenacity of the masonry and the earth, measured in the direction of the line of least resistance, differed so materially."

19. The rules given by Practical Miners being very discordant, it is desirable to inquire, by a comparison of these rules with the results of experience, how far they can be relied on; what they contain that is really true, or only specious, or altogether false: and as the results of the experiments at Metz can be most relied on, it is to them principally that our attention will be directed.

20. The first point to discuss is this, viz.: if masonry terminated by a vertical face, or a face a little inclined, offers as much resistance as masonry, or even earth, terminated by a horizontal plane, is it not more easy to throw down the masonry under the first condition, than to raise it under the second? Most practical miners conceive that there is no difference between the two cases. Let us see whether the experiments of Metz and Montpellier confirm this opinion.

21. In the breaches made at Metz in 1834, it has been seen (par. 16) that the mine was considered as made in masonry, for which a co-efficient of 2 was assigned, but it was loaded with only $\frac{3}{4}$ths of the computed charge. If the suppositions above alluded to had been true, the crater ought to have had a radius T, greater than 13·5 feet (4·15 metres); in place of which it is found that T equals 19·7 feet (6 metres); that is to say, that it was greater than the line of least resistance 15 feet (4·50 metres), and that the crater which had been made belonged to a surcharged mine in which $n = \frac{6}{4{\cdot}5} = 1{\cdot}33$. It is admitted that the breach at Metz was well made; the

splinters perhaps projected a little too far; but it is also obvious that the breach had not that form which theory assigned to it.

To explain the question more fully, let it be determined how a mine in ordinary level ground ought to be charged, to obtain a crater whose radius T will be 19·7 feet (6 metres). We should have $B = \frac{T}{8 \cdot 5}(1 \cdot 05 - 0 \cdot 05\, n) = 0 \cdot 705 \times 0 \cdot 92 = 0 \cdot 65$ metres (2·13 feet), corresponding to 551lbs. (250 kilo.) of powder. From this it will be observed that a crater of 19·7 feet (6 metres) radius, which would have been produced in common ground, has been made in a vertical wall with 463lbs. (210 kilo.) only; that is to say, with a charge less than that necessary for common earth, if the mine had been placed in a horizontal plane, and equal to that charge multiplied by a coefficient 0·84, or to a charge whose side B of the powder-box would be multiplied by 0·91.

See formula, paragraph 33.

22. It results therefore clearly, from a comparison of these facts, that the charges regulated as in common earth are quite sufficient to make a breach in vertical walls. Vauban and Cormontaigne maintained that they were so; and it remains to be seen if the charge so computed be not a little in excess, as also whether there is no danger of the crater being made on the surface, as all miners have feared it might be, even when in this direction there was a line of least resistance greater than that towards the masonry, conformably with the remark of General Guilleman, par. 18.

23. Once admitted that the distance to the terreplein may be less than twice the line of least resistance, it will be concluded readily that it is advantageous, for the more complete *bouleversement* of the masonry into the ditch, and for overcoming the tenacity of the earth, to raise the mine as high as practicable; that is to say, to begin the branch 1·8 foot (0·60 metre) or 2 feet (0·80 metre), or even 3 feet (1 metre) above the bottom of the ditch, and to incline the sole of the gallery upwards.

24. The powder ought not to be lodged in the masonry near the face of the wall, as is sometimes done in considering the operation simply one of demolition, because the advantage of shaking and loosening the earth ought not to be lost sight of. Besides, the importance of celerity in mining operations renders the cutting out of the masonry chamber for the powder-box an objectionable operation. The possibility of finding a portion of the counterforts standing after the explosion has generally been the cause of their being selected, in mining operations, as the points of attack. The position of the mines behind them satisfies to a sufficient degree the condition of having on the side of the terreplein a line of least resistance double that on the side of the masonry. It appears, then, proper to place the mines at the tail of the counterfort, and to allot one mine to each.

25. A breach 65 feet (20 metres) broad will, in general, be easily made in attacking three counterforts, and if the craters overlap much, the charge of the intermediate mine may be reduced. This reduction should, however, be a moderate one, provided the mine in rear is suppressed, which mine seems to have produced a bad effect in the experiment at Metz, prolonging the time necessary for preparing the mine, with the defect that the best position of the mine has never been accurately determined.

26. It has been seen that miners at present charge their mines to throw down masonry in higher proportions than to raise common earth: it is shewn that Vauban gives an equal charge for both cases, under the condition of having on the side of the earth a line of least resistance double that on the side of masonry; and by Colonel Cassieres, Director at Arras, that the position of the line of least resistance should not be lost sight of. Paragraph 18 cites the opinion of General Guilleman, that a line of least resistance on the side of the earth, equal to that on the side of the masonry, is sufficient to insure the fall of the revetment. The experiments made at Metz in

1834 lead to the same conclusion; and paragraph 13 shews that the experiments made at Montpellier in 1833 confirm those executed at Metz.

When a breach is made in an escarp, the mine is usually placed in such a position as to satisfy the rule of Vauban, viz., of having on the side of the earth a line of least resistance double of that on the side of masonry; but this rule no longer holds when it is a question to throw down a counterscarp,—an operation the Engineer is more likely to be called upon to perform than the former, on account of the perfection with which breaches are made by artillery. The position of the charge of a mine in relation to the masonry and to the earth is, then, the most important subject of the experiment, and with which it is necessary to commence, since the charge and the disposition of the mine depend upon the result.

Plate XII. fig. 10.

27. It appears, from the Report of the School of Montpellier in 1837, that some experiments had been instituted at Metz and at Arras in 1831, on the powers of resistance of masonry galleries. They were exposed to the effects of the explosion of 441 lbs. (200 kilo) placed at the bottom of a shaft hastily sunk without being lined with frames, and not tamped, but having a line of least resistance of 13·2 feet (4·10 metres). The charge had been doubled, to allow for no tamping being applied. From the results obtained the following conclusions are drawn:

Diagram *a*.

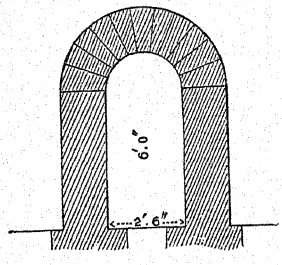
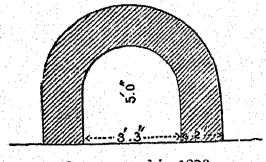
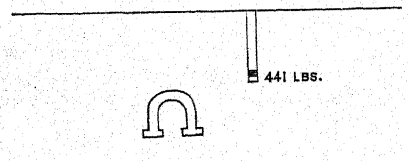


Diagram *b*.



Constructed in 1829.

Diagram *c*.



1. That a gallery constructed in masonry resists a mine placed above it or on its flank at a distance from it equal to $\frac{8}{3}h$, and is ruptured at $\frac{5}{3}h$ (fig. *a*.)

2. That a branch with masonry of the same thickness resists $\frac{4}{3}h$ on the side, but gives a little more resistance above the extrados (diagram *b*).

The experiments made at the School of Montpellier in 1837 were intended to prove if a branch can resist the explosion of a mine placed above it at a distance $\frac{8}{3}h$.

The branch was disposed as shewn in the annexed diagram *c*. The distance of the mine from the gallery was $\frac{8}{3}h$. The shaft was tamped by throwing earth rapidly into it, without tamping, ramming, or its surface being levelled.

It would have been desirable not to have filled the shaft at all, in order to try if, in doubling the charge, the tamping can be dispensed with. The branch was ruptured for a length of 10 feet (3 metres). From this experiment, and those made at Metz in 1831, it may be inferred that a branch in masonry having a thickness of 1·5 feet (0·45 metre) at the arch is broken by the explosion of an ordinary mine, when its distance from the chamber is not more than $\frac{8}{3}$ of the line of least resistance of the crater.

28. The following extract is taken from a work by General Chasseloup, published in 1811.

"It is usual to demolish the revetment in fortifications by placing the mines in the masonry; their explosion succeeds generally in throwing down the wall, but leaves

the earth of the rampart, and even the parapet, standing vertical. I have endeavoured, however, by these explosions to produce a greater effect.

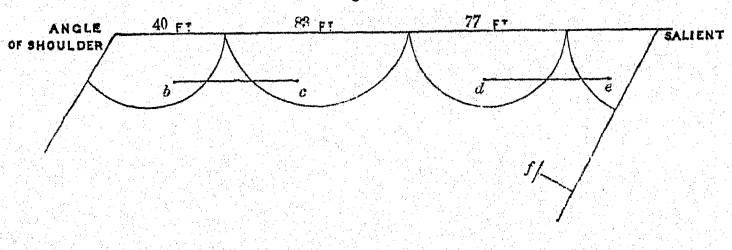
"In place of employing small charges, I have used large ones, having $n=2$ placed at the tails of the counterforts (fig. 24, Plate XV.). In charging the mines at the salient, 19·43 (18 lbs.) were allowed for each 9·684 cubic yards (toise cube), for the faces 17·27 (16 lbs.) per toise were allowed, because the ground was of ordinary consistence. The volume of a common mine, with a line of least resistance of 22 feet 4 inches (21 feet French), is 784 cubic yards (81 cubic toises), which at 19·43 lbs. (18 lbs. French) per toise, will require a charge of 1578 lbs. (1462 lbs. French) for the salient, and 1404 lbs. (1300 lbs. French) for the faces: let these charges be augmented, not in the ratio of the cubes of the radii of rupture, as Belidor has proposed, but in that of the radii of the crater, which will increase the above computed charges to 3156 lbs. (2924 lbs. French) and 2808 lbs. (2600 lbs. French).

"The tamping was made in brick and in turf; the mines *b* and *d* were completely tamped, but the interior mines and that of the salient were not completely so, a space being left about the charge. (See Plate XV. fig. 24, and the following diagram *d*).

COMPARATIVE TABLE OF RESULTS.

Explosion.	Indication of the Mine.	Charge for each mine in lbs.	Force of the powder.	No. of cubic yards of empty space left.	No. of cubic inches of space left for each lb. of powder.	Volume raised in cubic yards.	Cubic yards raised per lb.	Relation of the effects produced by the mines.
1	Mine placed at the angle of the shoulder, 110°. *b*.	3156	26	,,	,,	4055	1·28	1·056812
1	Mine marked *c*, in diagram *d*, in the left face.	2808	19	13·4	224	3727	1·32	1·092763
2	Mine *d*, in the same face.	2808	19	,,	,,	3413	1·21	1·000000
2	Mine *e*, in the flanked angle, 77°.	3154	19	20·5	300	5232	1·65	1·321181
3	Mine *f*, placed in the right face.	3666	19	26·7	340	4578	1·25	1·020048

Diagram *d*.



29. "The examination of the breaches shews,—1st, That the part of the left face demolished by the mine *c*, which had a space left round the charge, was longer than that overthrown by the mine *d*, which had been completely tamped. 2ndly, That the mine at the flanked angle, where the space left round the charge had been increased, had overthrown the escarp 32 feet more than the mine at the angle of the shoulder, where the tamping had been completed. 3rdly, That the mine *f*, on the right face, having a greater space left round the charge than the mine *c* on the left face, had also demolished a greater length of escarp. By the Table already given, it is also manifest, —1st, That the total effect produced by the mine *c* on the left face, which had a space untamped in the vicinity of the charge, was greater than that produced by the explosion of the mine at the angle of the shoulder, charged with a greater quantity of powder and of a better quality. 2ndly, That the effect of the mine *f*, on the right face, is greater than that of the mine *d* of the left face, which had no space left round its charge, but smaller than that produced by the mine *c* of the same face, which had a less similar space left. 3rdly, That the mine at the flanked angle has produced an effect greater than any of the others.

30. "It is clear, then, that the space left around the charge is to a certain point advantageous, beyond which point it diminishes the explosive effect; but it has always the advantage of directing the greatest effect of the mine in the required direction.

"It has been observed in the experiments which have been made known, that in all mines where spaces or voids have been left around the charges, very little smoke has been observed after the explosion: the contrary generally takes place in the explosions where no space has been left. The smoke is mixed also with much flame, which is thrown out to a distance of 42 yards (20 toises). This fact evidently proves that in leaving no space round the charge in mines which are a little surcharged, a part of the powder is not ignited till after the explosion, or, at least, till after a great motion has taken place from the combustion of part of the powder, which must necessarily produce a diminished effect from the explosion of the whole.

31. "It has also been observed that mines placed in obtuse angles have produced a greater effect than when placed behind a straight revetment, and that mines placed in acute angles produce greater demolition than when placed in obtuse angles.

"Several methods of arriving at the mines were employed in the operations which have been detailed. The bastion had nearly the same perimeter as one which had been demolished with a minimum quantity of powder, employed in the usual manner by ordinary mines. In comparing the expense entailed by each method, by taking into consideration, on the one hand, that when large charges are employed, although a greater quantity of powder is consumed, yet a greater length of revetment is overthrown, and the material is broken up and divided;—on the other hand, the necessity, when ordinary charges are employed, to commence afresh, after overthrowing the revetment, with a new series of demolitions, in order to break up again the masses of masonry, to make the material available for further use,—the earth it is necessary to bring, to produce the same effect, as regards the ascent of the breach, as when surcharged mines are used,—it will be found that if one-tenth in economy of powder be obtained by the ordinary mode of attack in demolitions, yet with surcharged mines is the advantage of a great saving of time: for in fifteen days as much can be done as can be effected in three months when the ordinary methods are employed, while very much labour is saved in executing the operations by the former methods.

CONCLUSION.

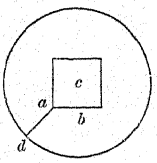
32. "After what has preceded, and, above all, after projects of demolition have been made under circumstances where walls of every variety of thickness and quality of masonry could be commanded, it may be enunciated as certain,—

1. That the maximum effect takes place when the space occupied by the powder is to the volume of space left around the charge in the ratio of 1 to 10, assuming that 1 lb. occupies 27 cubic inches.

2. That the effect of a mine is more powerful in the direction in which the space is left than in any other, provided the ratio alluded to be not exceeded.

3. That with the same quantity of powder, placed under similar conditions, to destroy a straight wall, a salient, or a re-entering angle, the angles of demolition whose vertices are in the centre of the charge, and the sides tangent to the excavation, are in the relation of α; $\alpha + 90$; $\alpha - 90$; so that the maximum effect is in a salient angle, and the minimum in a re-entering angle; and by taking advantage of this principle, a tower has been breached without ruining a casemate which was within. If the charge had been placed at b, the casemate would have been destroyed; by placing it at a two feet from the angle, it was preserved, although the line of least resistance $a\ d$ had a length of 11 feet.

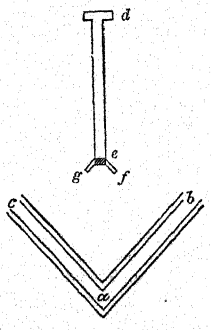
Diagram *e*.



"That it is necessary always to place the mines above the bottom of the ditch, or otherwise, if it be placed below that level, to remove the earth from the point of the foundation; that is to say, to dig a ditch in the ditch.

"Also, that if it be proposed to destroy two galleries, $a\ b$ and $a\ c$, after driving the gallery $d\ e$ for the necessary length, two small returns $e\ f$ and $e\ g$ should be added, which would be left empty, the charge being placed at e.

Diagram *f*.



"It appears, also, from experiment, that the less the tenacity and density of the soil, the greater should be the space left round the charge.

"Powder has been frequently employed in loose heaps, unconfined in boxes or chambers, particularly for the destruction of bridges, by placing a quantity along the summit of the extrados of the arch; but the Chief of Battalion of Engineers, Breuille, an Officer distinguished for his knowledge of mining, states, that by placing the charge under the arch, the demolition will be more complete: he proposes simply to place the powder in a small case and suspend it from above, the case being brought close to the soffit of the arch."

He states also, that 150 lb. of powder, placed against a wall, destroyed 25 feet of it. The thickness is not given.

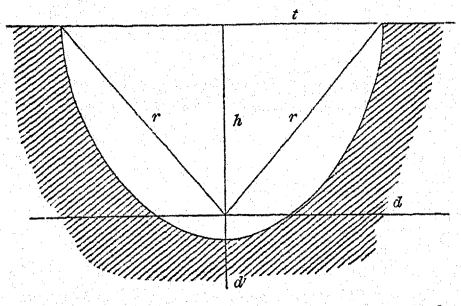
Formulæ for the Charges of Mines.

33. If h represent the line of least resistance of a mine; t, the radius of its crater; r, its radius of explosion; d, its horizontal radius of rupture; and d', its vertical radius of rupture; let $\frac{t}{h} = n$. The mine is called an ordinary or common mine

when $t = h$ or $n = 1$. It is said to be surcharged when t is greater than h, or n is greater than 1; and undercharged when t is less than h, or n is less than 1.

Common Mines.—Let c represent the charge in lbs. of an ordinary mine, the powder having a density of 0·91, placed in ground of average density and tenacity, that is, requiring about 1·337 lbs. of powder to raise a cubic yard; c' the charge of a surcharged mine; and $c_,$ that of an undercharged mine: also, let b, b', $b_,$ represent the sides of a cubical box capable of containing the charges c, c', $c_,$; then there will result $c = 1687{\cdot}5\ b^3 \times 0{\cdot}91$: representing by the small letters the elements of one mine, and by large letters those which belong to a second,—equations or proportions are obtained as follows:

Diagram *g*.



$$(2). \qquad \frac{c}{C} = \frac{h^3}{H^3} = \frac{t^3}{T^3} = \frac{r^3}{R^3}.$$

Performing the same operation in the different formulæ recapitulated at page 75 of the 'Manual for Practical Miners,' two series of formulæ, as given below, will be obtained, of which the first is that of the miner in terms of c and h^3: the second contains only simple terms of b and h.

Mines.

Common mine, $n = 1$.	(3). $C = \frac{11}{8}\ h^3\ 1{\cdot}337 = 2{\cdot}451\ h^3$.	(3′) $b = \frac{h}{8{\cdot}55}$.
Surcharged from $n = 1$ to $n = 3$	(4). $C' = C\ (0{\cdot}15 + 0{\cdot}85\ n)^3$.	(4′) $b' = b\ (0{\cdot}15 + 0{\cdot}85\ n)$.
Surcharged from $n = 1$ to $n = 5$	(5). $C' = 2{\cdot}451\ T^3 (1{\cdot}05 - 1{\cdot}05n)^3$	(5′) $b' = \frac{T}{8{\cdot}55}(1{\cdot}05 - 0{\cdot}05\ n)$.
Surcharged from $n = 1$ to $n = 1{\cdot}5$	(6). $C' = 2{\cdot}451\ T^3$.	(6′) $b' = \frac{T}{8{\cdot}55}$.
Undercharged, when n less than 1,	(7). $C' = C\left(\frac{4 + 3n}{7}\right)^3$	(7′) $b_, = b\frac{4 + 3\ n}{7}$.
Common, overcharged, and undercharged,	Radius of rupture { Horizontal (8) $d = \frac{7}{8}\ h$ (8′) $b = \frac{1}{15}\ d$. Vertical (9) $d' = 1{\cdot}41\ h$ (9′) $b = \frac{1}{12}\ d'$.	

Camouflets.

Maximum at a distance h from the gallery,	(10) $C = C\ (\frac{4}{7})^3 = 0{\cdot}45 h^3$.	(10′) $b = \frac{1}{15}\ h$.
Maximum against a gallery situated at a distance d on the same level,	(11) $C' = 2{\cdot}451\ d^3\ (\frac{4}{7})^3 = 0{\cdot}45\ d^3$.	(11′) $b = \frac{1}{15}\ d$.
The same at distance d', vertically below.	(12) $C = 2{\cdot}451\ d'^3 \left(\frac{1}{\sqrt{2}}\right)^3 = 0{\cdot}86\ d^3$	(12′) $b = \frac{1}{12}\ d$.

Note.—In these equations the charge is in lbs.; b is supposed to be expressed in yards. C denotes common mine; C′, overcharged; $C_,$ undercharged; b, side of box in common mine; b', ditto overcharged; $b_,$ ditto undercharged.

TABLE *shewing the Charges in Soil of different Natures compared with ordinary Earth, or the Co-efficient of* c *; as also the corresponding Dimensions of the Powder-box, or the Co-efficient of* b.

NATURE OF SOIL.	Density.	Co-efficient of *c*.	Co-efficient of *b*.
Argillaceous soil mixed with sand or gravel, called in French, ordinary earth	1·88	1·00	1·000
Common earth (*terre commune*)	1·37	1·12	1·038
Sand	1·79	1·25	1·079
Damp or wet sand	1·91	1·31	1·092
Earth mixed with small stones	1·92	1·41	1·120
Clay mixed with loam	2·01	1·55	1·157
Argillaceous earth mixed with flints	2·31	1·69	1·190
Rock	2·31	2·25	1·310
New or old masonry in a damp condition, not cemented by hydraulic lime	2·31	1·30	1·090
Common masonry	2·31	1·66	1·183
Very good new masonry	2·31	2·25	1·310
Masonry in Roman cement	2·31	2·90	1·425
Good masonry, when disposed vertically, as in revetments	2·31	0·83	0·910

The formulæ 7, 12 : all the formulæ in terms of b are taken from an unpublished Memoir, which, however, has received the approval of the Committee of Fortification. They tend much to simplify the calculations for the charges of mines fired under various conditions of media. In the same memoir the two following theorems are enunciated, viz.

1. For the same charge, the common mine is that the volume of which is a maximum.

2. For the same charge, the surcharged mine, in which $n = 2$, is that which produces the greatest surface effect.

Note.—In giving this Memoir of a Committee of Engineer Officers in the French Service, and the rules laid down and formulæ adopted, it is not intended that they should supersede the valuable information collected under the article 'Demolition' in this work, and more particularly in Table VI. of that article.—*Editors.*

APPENDIX IV.—VENTILATION OF MINES.*

Great attention must be paid to ventilation in driving extensive galleries, as the gas generated by explosions of gunpowder, or contained in the soil, collecting, particularly in ascending and descending portions, has sometimes suffocated the miner before the extinction of his light has warned him of its presence; and even under ordinary circumstances, the air becomes so much vitiated by the presence of the workmen alone, that a small gallery cannot be safely driven more than about 60 feet without a ventilating apparatus : apertures should therefore be bored up to the surface of the ground, at intervals beyond that distance from the entrance, taking care to conceal their position from the enemy, if possible ; and communications may be made with adjacent galleries to create a draught.

Mechanical means are also required for producing a circulation of air, so as to substitute fresh air for that which is impure : for this purpose tubes are fixed, through

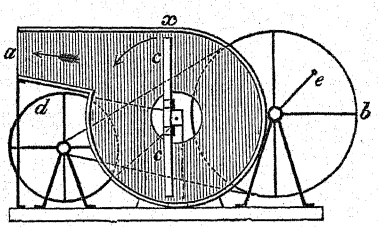
* By Lieut.-Colonel Bainbrigge, R.E.

which fresh air may be forced in, or bad air extracted; but as there may be a large quantity of noxious gas in the soil, ready to supply the place of that extracted, the system of *forcing in* fresh air has generally been preferred in military mining.

The tubes used for ventilation have been constructed of iron, but gutta-percha or vulcanized india-rubber would probably form better materials for them.

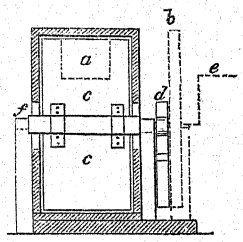
A cylindrical bellows has been used for forcing in the air, but this has proved inefficient; and as the French and Germans use fanning machines for that purpose, it is probable that they may be employed with advantage for ventilating extensive galleries: therefore a sketch of one lately made by Sergeant Lewis, Royal Sappers and Miners, is here given (figs. 1 and 2), with some modifications required to render it

Fig. 1.



Longitudinal Section (scale 2 feet to an inch).

Fig 2.



Section at *x*.

efficient. The pipe for conveying the air from *a* should be at least 6 inches in diameter, and should be attached to the top of the gallery, and the box in which the fans revolve may be made of wood or sheet iron; it has only two fans, formed by a single board *c c*, experience having proved that a greater number do not increase the power: the axle to which it is attached is turned by a strap (shown by dotted lines) passing round the tire of the wheel *d*, the axle of which is turned by another strap passing round the tire of the wheel *b*, which is worked by the handle *e*: thus the air in the box is made to acquire a centrifugal motion, and passes rapidly out of the exit pipe *a*. By attaching the tubes to the aperture *f* (fig. 2), and closing the opposite one, the bad air could probably be *drawn out* of the gallery and driven away at *a* in the same way, if that be preferred; and the size of the machine may be increased, or additional ones applied, if more power be required.

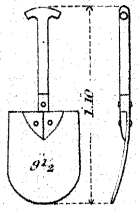
Note.—As in many cases it may be found desirable to *exhaust the foul air* in a military mine, the following description of Mr. Haig's patent pneumatic engine, invented for the purpose of purifying the holds of vessels, is here inserted.—*Editors.*

"The want of an efficient mode of ventilation has long been seriously felt, particularly in the Navy, and large Public Buildings: many plans for obviating this great evil have been suggested, and large sums expended in attempting to bring them into practice. They have, however, been found either too costly, or incapable of accomplishing the object for which they were designed.

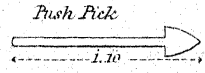
"The importance of a free circulation of atmosphere in all places where we have to exist is so well known and admitted, and so much has been said and written upon the subject by scientific and medical men, that it is unnecessary here to detail the baneful effects that ensue from inhaling contaminated atmosphere.

"In bringing forward a means by which this object can be obtained, the inventor feels satisfied, that as soon as his method becomes known, from its simplicity of construction, and moderate cost, it will be universally adopted in all places requiring

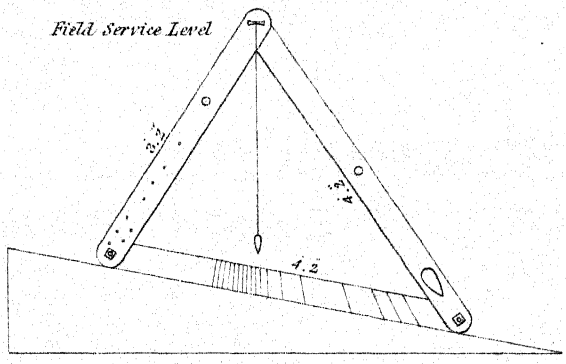
Miners Shovel

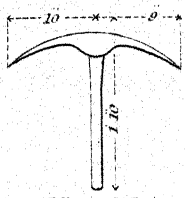


Push Pick



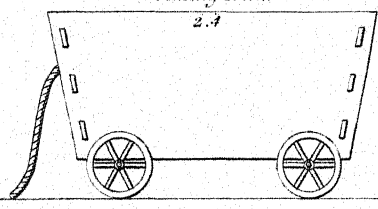
Field Service Level



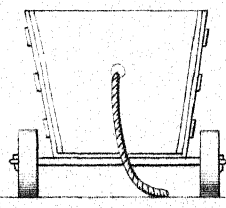


Miners Pick

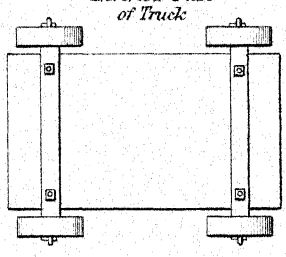
Mining Truck



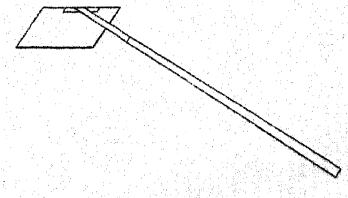
End View



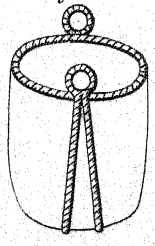
Inverted Plan of Truck

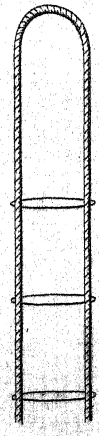


Rake



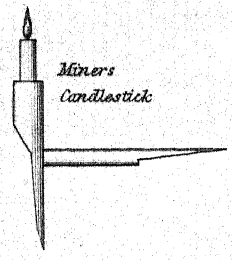
Canvas Bucket





Rope Ladder

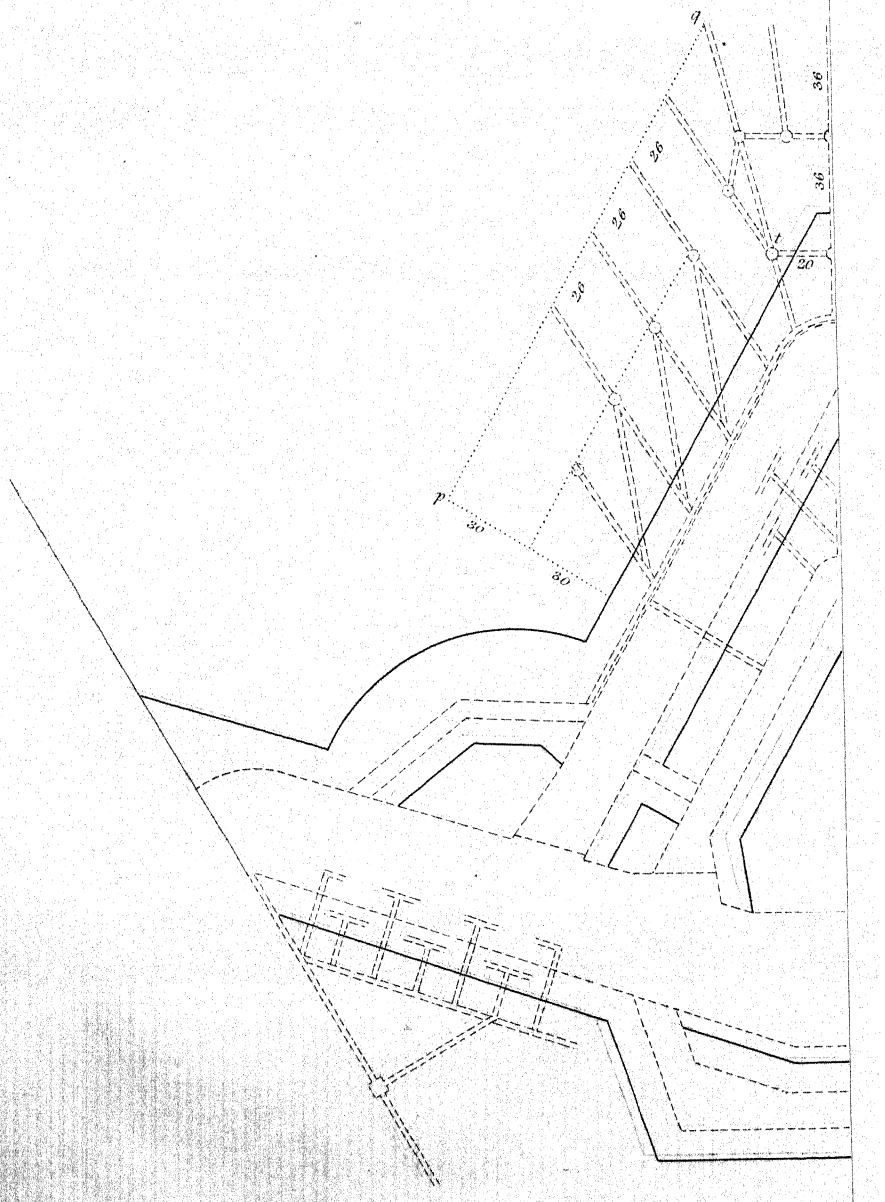
Miners Candlestick



J.W. Lowry fc.

London, John Weale 1849.

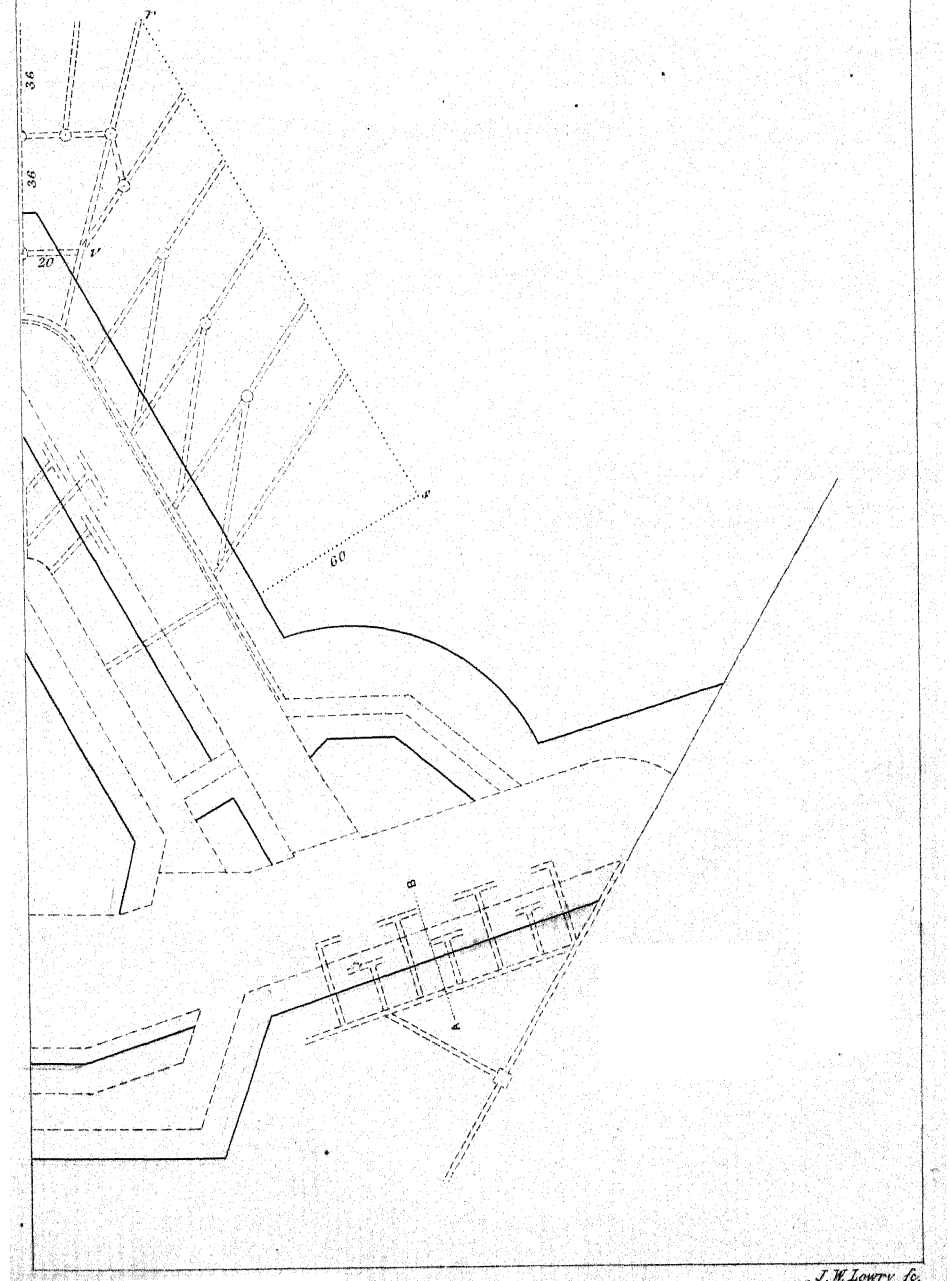
DUFOURS SYSTEM OF COUNTERMINES.



Scale One Inch = 60 Yards

London, John Weale 1849.

Mem. The dotted Lines represent the Masonry on the Level of the Countermines.

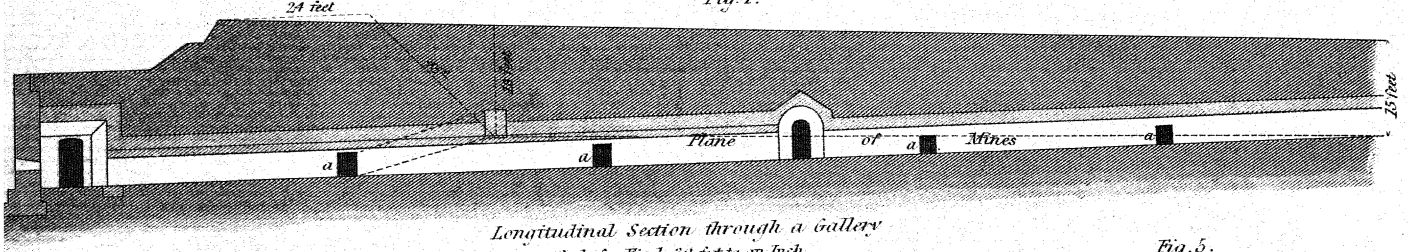


J. W. Lowry fc.

London, John Weale 1848.

SECTION & PROFILES OF DUFOURS COUNTER MINES.

Fig. 1.



Longitudinal Section through a Gallery

Scale for Fig. 1. 30 feet to an Inch

Fig. 2.

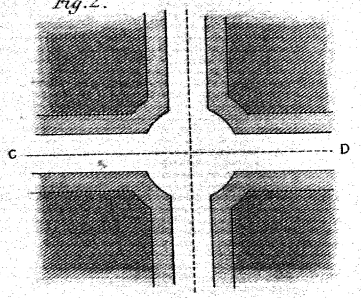
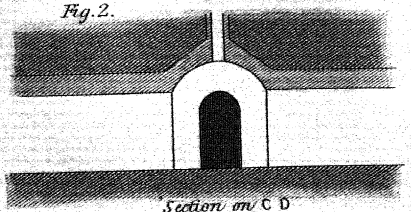


Fig. 2.



Section on C D

Fig. 3

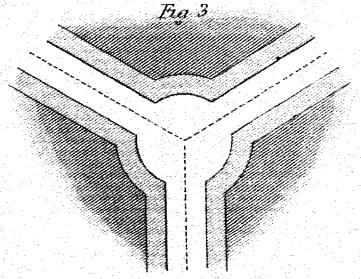
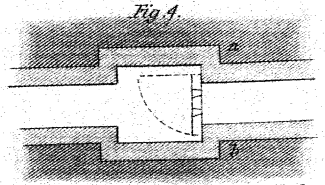
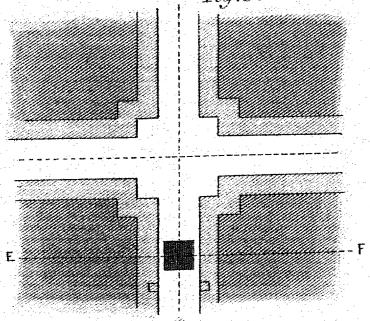


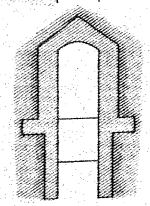
Fig. 4.



Scale for Fig 2.3.4. & 5. 15 feet to an Inch.

Fig. 5.





Section on E F

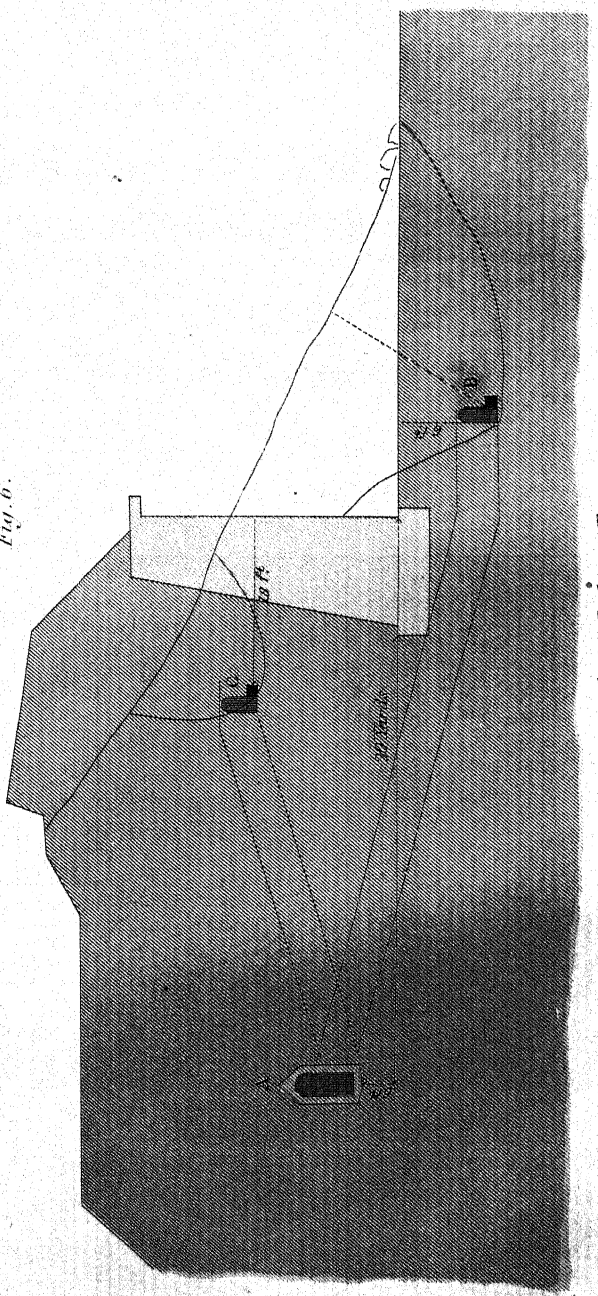
John Weale 59 High Holborn 1846.

J.W. Lowry sc.

MINING. MILITARY. Pl. 4.

Section on A B Pl. 3.

Fig. 6.

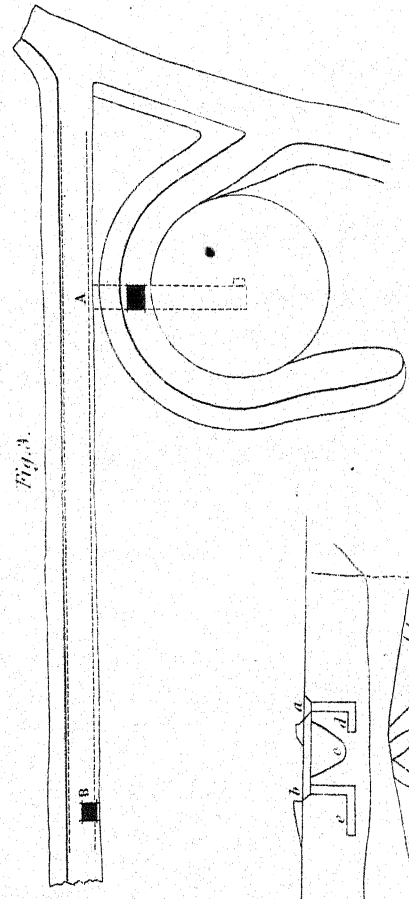


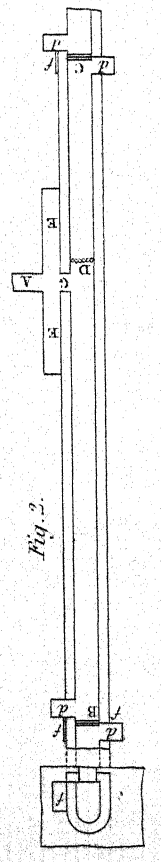
Scale One Inch = 20 Feet.

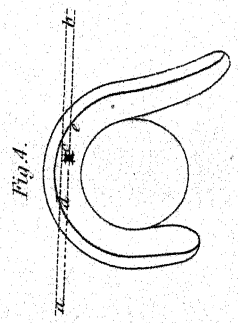
J.W. Lowry fr.

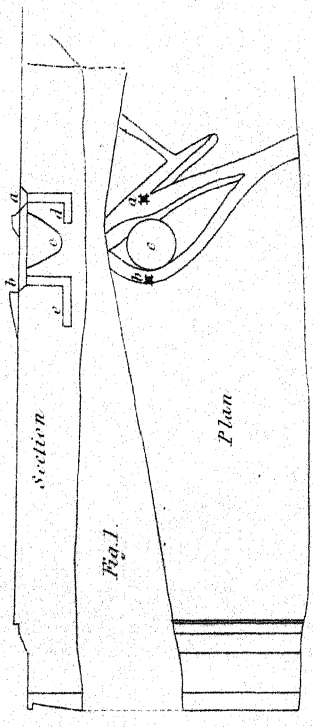
London, John Weale, 59 High Holborn, 1849.











J. T. del. R.E.

J. W. Lowry sc.

John Weale, 59. High Holborn 1840.



Lt. Addy R.E.

John Weale, 59 High Holborn, 1849.

J.W. Lowry sc.

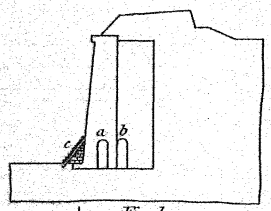
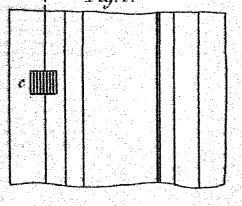


Fig. 1.



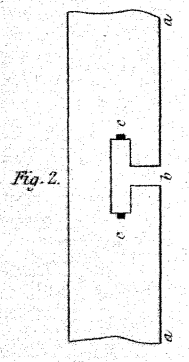


Fig. 2.

Fig. 3.

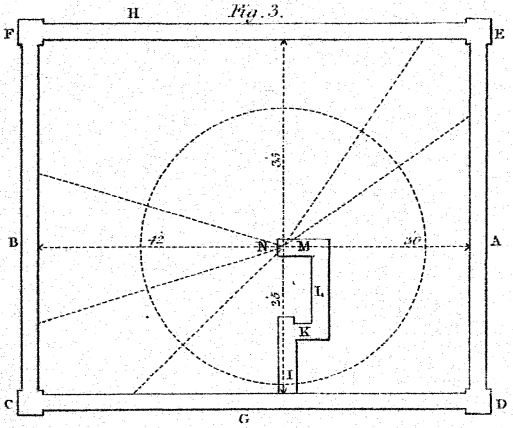


Fig. 5.

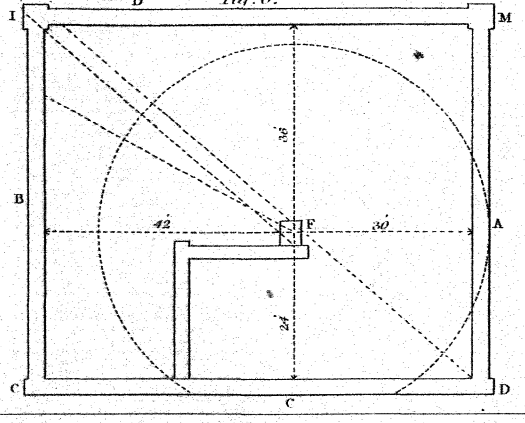


Fig. 4.

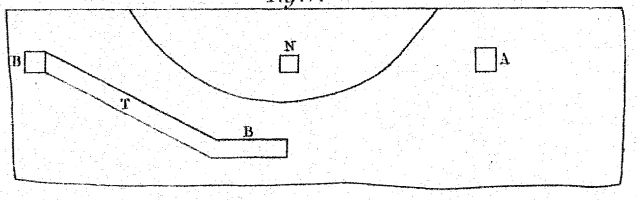


Fig. 6.

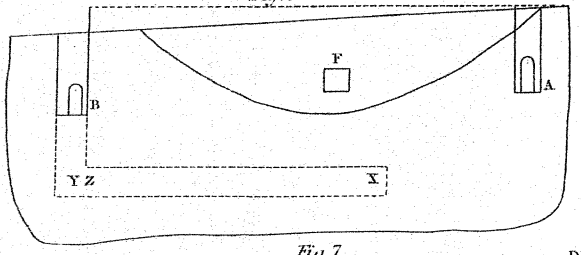
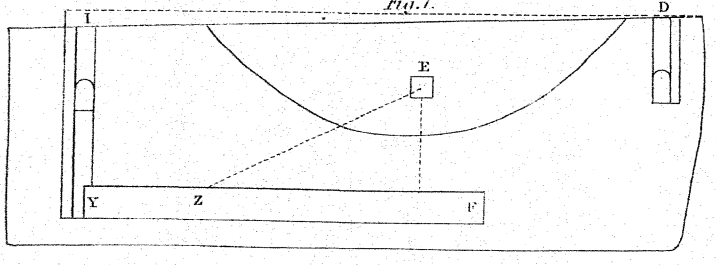
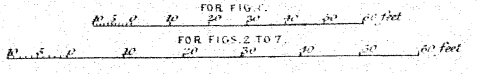


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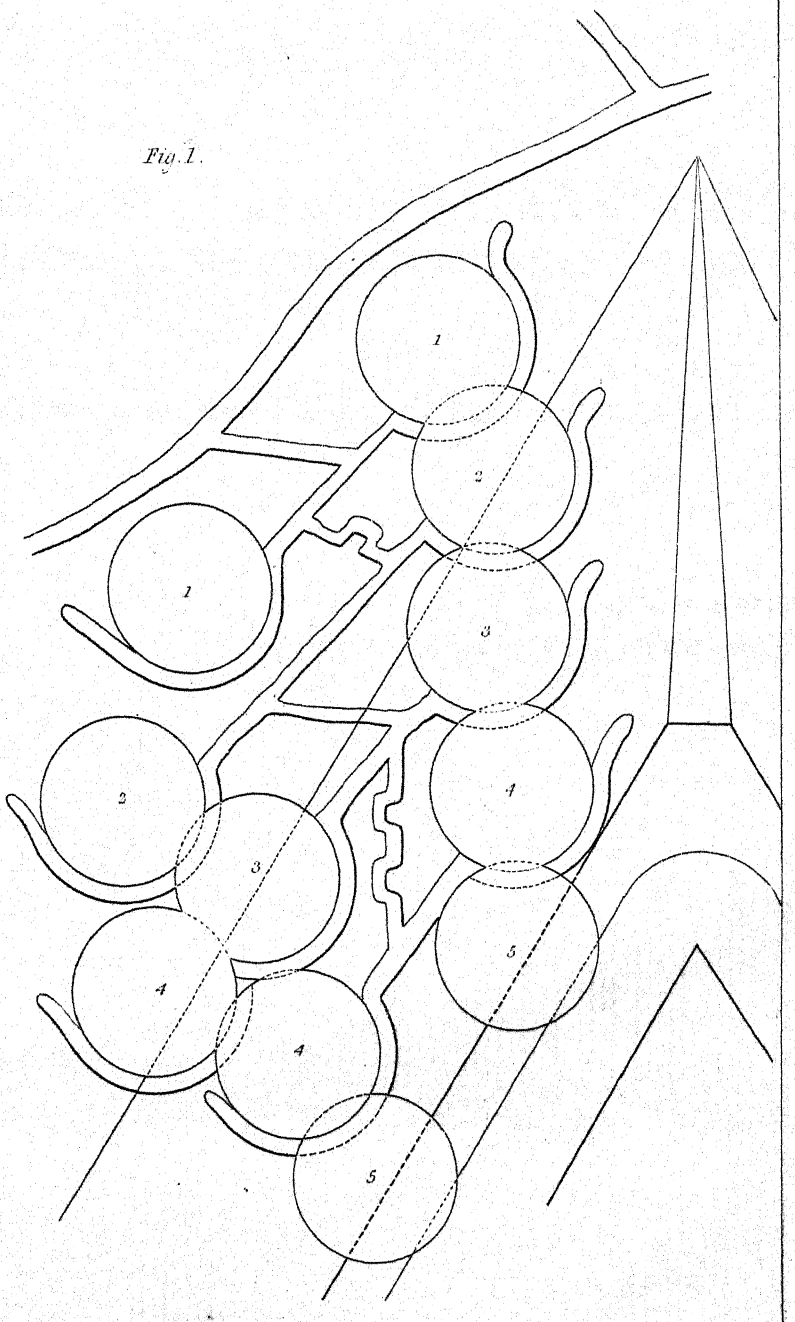




French

MINING. MILITARY. PLATE 7.

Fig. 1.

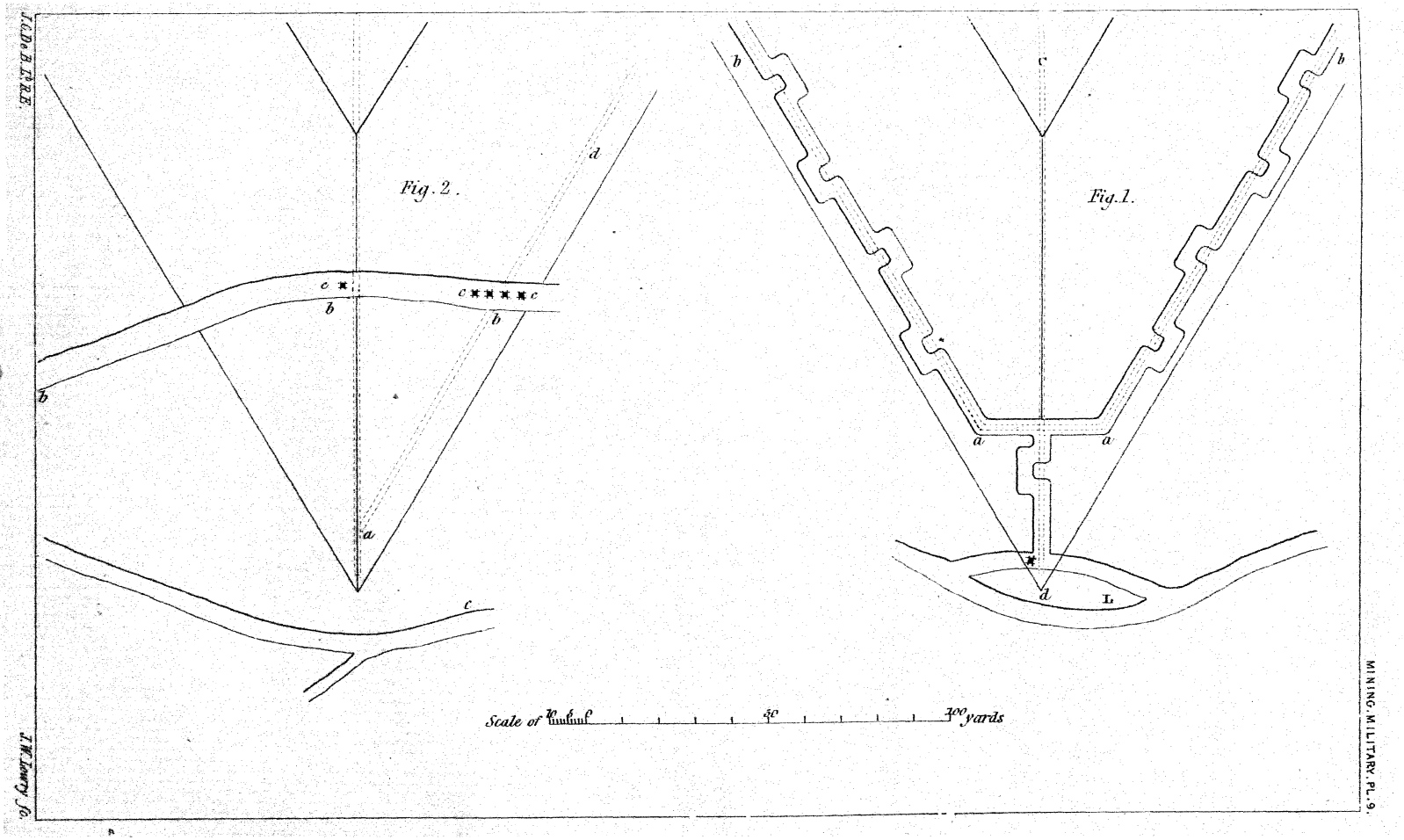


J.C.De B. 1st R.E.

J.W. Lowry fc

John Weale 59 High Holborn 1849.





MINING. MILITARY. PL. 9.

MINES — *Appendix 2.*

Fig. 1. Profile of Bastion N°7 at Bapaume

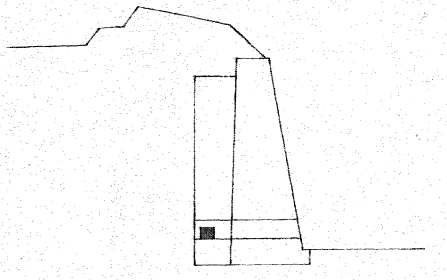


Fig. 2. Disposition of Vauban.

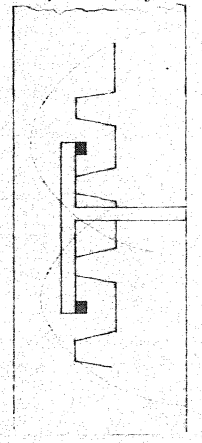
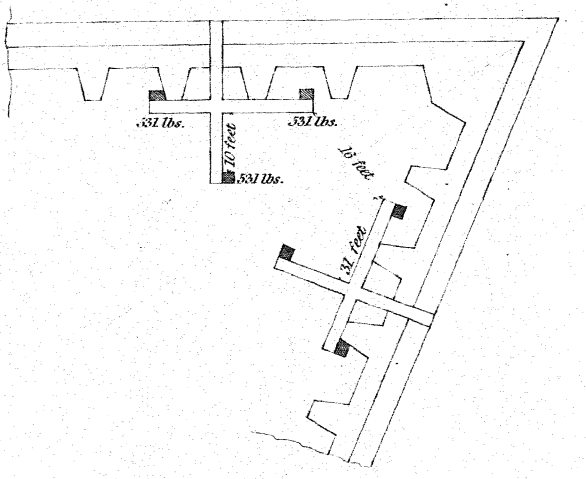


Fig. 3. Plan of the Disposition of Cormontaigne.





Scale of 0·002

John Weale, 59, High Holborn, 1848.

J.H. Lewis Sc.



MINES — *Appendix 2.*

Fig. 4. Disposition of Gillet

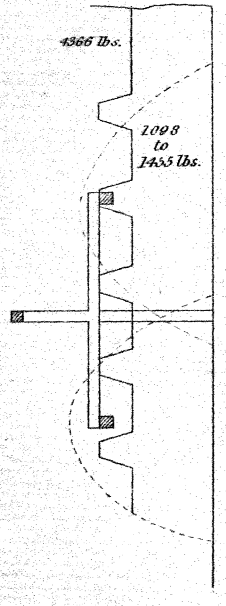


Fig. 5. Lunette St Laurent Antwerp 1832.

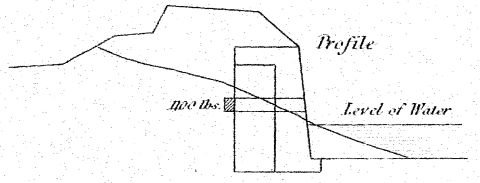


Fig. 6.

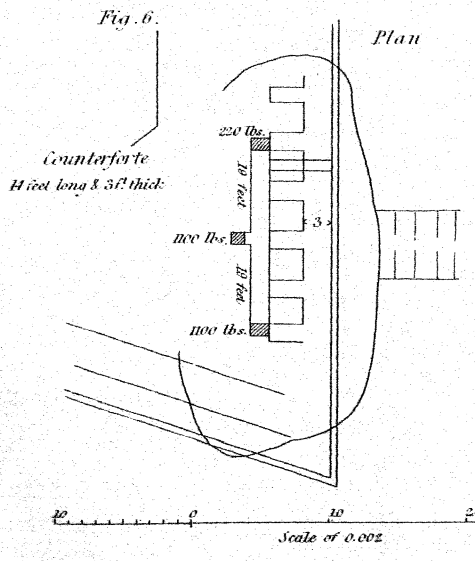


Fig. 7. from Laisne Aide Memoir.

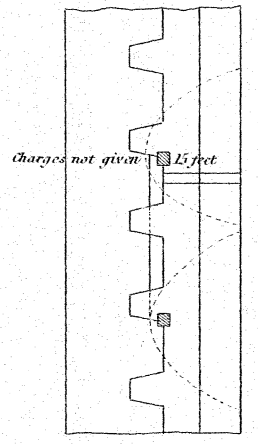
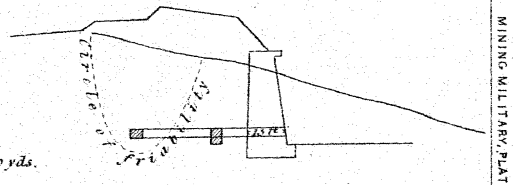


Fig. 8. Profile of the Breach at Metz in 1834.



John Weale, 59 High Holborn 1846.

J.M. Lewis del.

MINING MILITARY. PLATE II.

MINES — Appendix 2.

Fig. 9.

Plan of Breach at Metz in 1834.

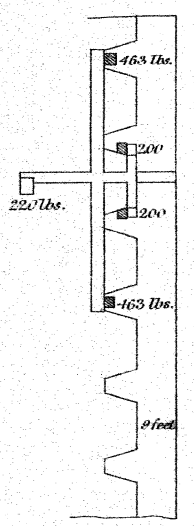


Fig. 10.

Breach in C'scarp Montpellier in 1833.

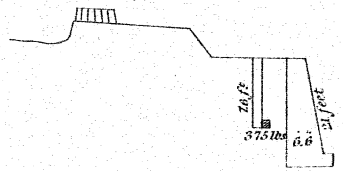
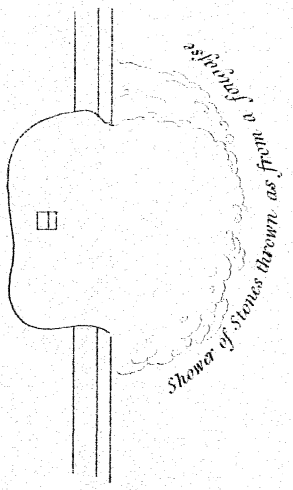
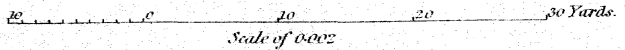


Fig. 10.

Plan

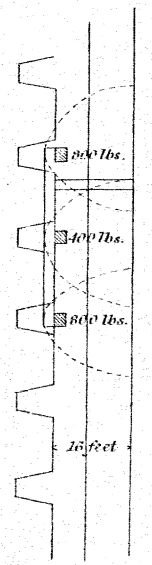




Scale of 0.002

Fig. 11.

Project of the School at Arras in 1847.



John Weale, 59 High Holborn, 1849

W. Lowry Sc.

MINING MILITARY. PLATE 12.

MINES *Appendix 2.*

Fig. 12. Demolition of Turin.

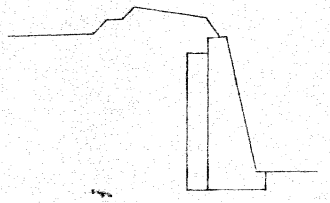


Fig. 12. Plan.

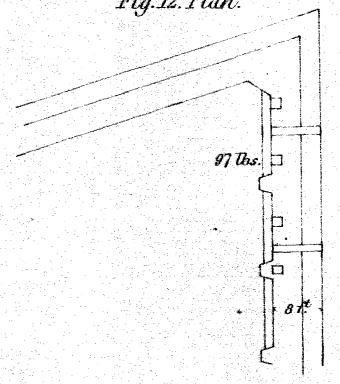
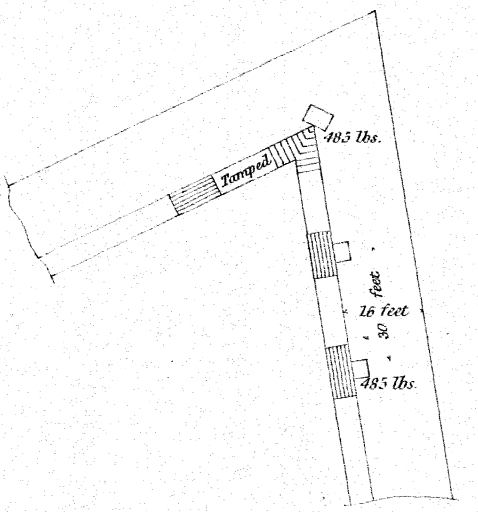


Fig. 13. Demolition of Verona.



Scale of 0·002

John Weale, 59 High Ho Born, 1842.

J.M. Lowry, Sc.

MINING MILITARY PL. 13.

MINES. Appendix 2

Fig. 14. Profile of Eland Bastion Vienna.

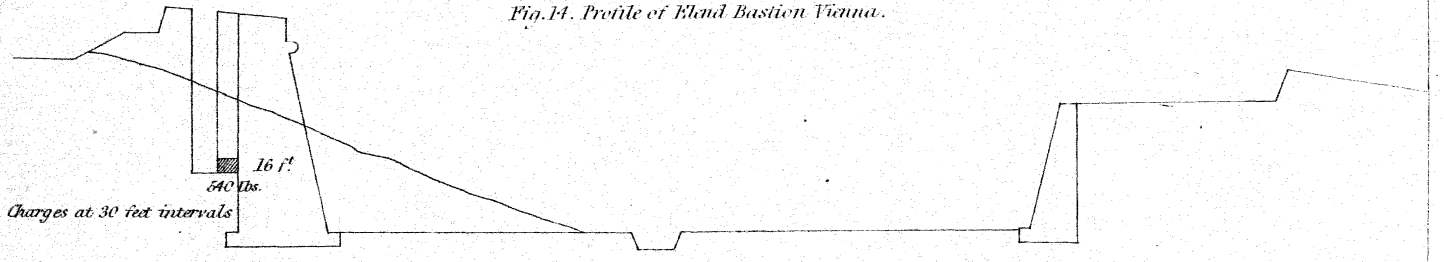
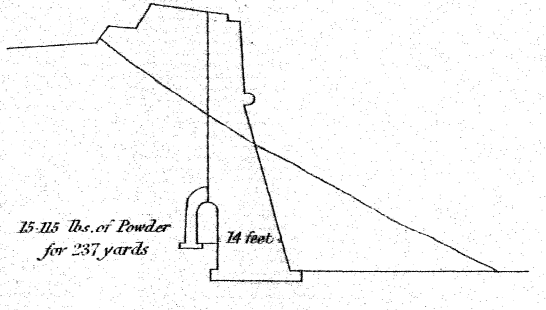


Fig. 15. Profile of Bastion Möleck.



Scale of 0·002

Fig. 16. Profile of Shaft N°1. Ulm 1807.

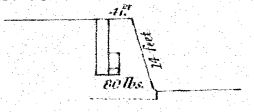


Fig. 17. Plan.

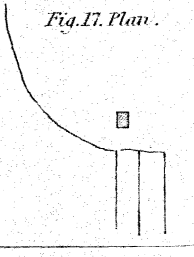


Fig. 18. Profile of Shaft N°2. Ulm 1806.

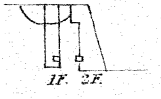
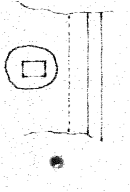


Fig. 19. Plan.



John Weale 59 High Holborn 1849.

J.M. Toms sc.

MINES *Appendix 2.*

Fig. 20. Profile of Bastion, Burg. Vienna. 1807.

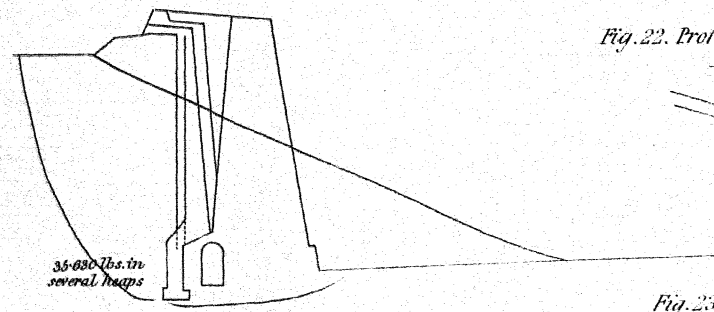
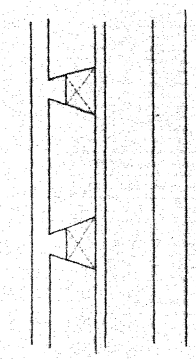


Fig. 21. Plan of Bastion for 320 Yards.



Scale of ·002.

Fig. 22. Profile of C'scarp at Metz 1831.

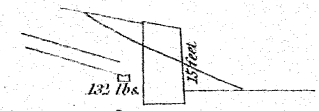


Fig. 23. Plan of C'scarp.

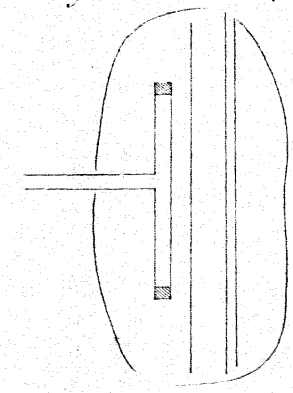


Fig. 24. Plan of the Experiment reported by Gen.l Chasseloup.

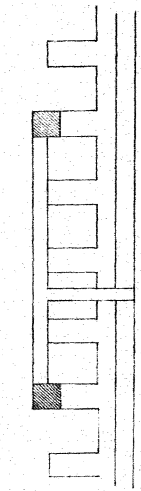
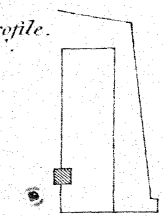


Fig. 25. Profile.

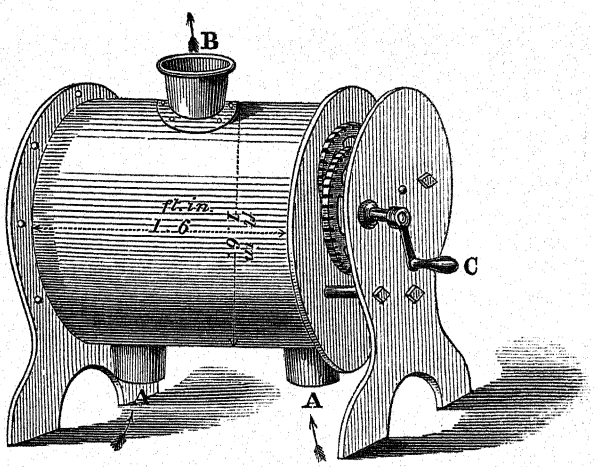


London, John Weale, 59 High Holborn, 1846.

J. Lowry, Jr.

the aid of artificial means to keep up a constant current of wholesome air. The fact of its having been successfully applied in the ship 'Sylph,' and also in the 'Rosamond' steam ship, is a sufficient guarantee to warrant the inventor in coming to this conclusion.

"From a series of experiments made at the patentee's manufactory on the power of a machine 1 foot 6 inches in diameter, constructed upon his plan, it was found that nearly 6000 cubic feet of air could be removed under the ordinary pressure in an hour. If, therefore, it were required to ventilate a vessel of 1000 tons (which is about the size of the 'Rosamond'), it would be found that the fore-part contains about 21,815



Elevation of Haig's Patent Pneumatic Engine, capable of discharging 6000 cubic feet of air per hour.

A, A. Two 3½-inch exhaust pipes. } These pipes may be extended as required.
B. 3½-inch delivery pipe. }
C. 5-inch winch or handle.

cubic feet, the middle or engine-room 36,040 feet, the after-part 12,000 feet, making a total of 69,855 cubic feet: supposing half of this space to be occupied with stowage, the other half, or 34,927 cubic feet of air, has to be removed, which might be done in an hour with seven machines of the size of the one above described; but if it were required to be done in less time, this might be readily effected by increasing the size of the machine, or making use of a greater number."

MOUNTAIN ARTILLERY.*—Various opinions have been entertained on the subject of Mountain Artillery and the service it is capable of rendering to an army. By some, the lighter guns usually employed, and especially those carried on mules, have been considered to be utterly worthless; by others, their value has been overrated. It cannot for a moment be supposed that any such artillery, in any possible number, can be compared in effect with good Field Batteries capable of overcoming all the ordinary difficulties of ground; but in the mountains, excepting the immediate vicinity of the great roads which traverse them, the best equipped field artillery is liable to become paralyzed by obstacles that it cannot master, and to be

* By the late Lieut.-Col. Colquhoun, Royal Artillery.

rendered not only useless, but a cause of serious embarrassment to the troops to whom it is attached. And the question then arises, whether for a part of the services which artillery can render, and in the particular circumstances which present themselves in mountain warfare, guns of lighter weight, and those even which admit of being carried on mules, may not be employed with effect.

The solution of this question is obviously dependent on the nature of the country and of the difficulties it presents, and is therefore one of degree,—of which the conditions may be thus stated, it being premised that in the observations which follow, it is not proposed to enter on the subject of the *Passage of Mountains* by field or heavy artillery,—an operation of much interest, but which does not belong to the subject; for under such circumstances, the gun and its appurtenances become mere articles of transport, and all their powers dormant for the time. An example of this operation, the most brilliant that history presents, and that well deserves to be studied in all its details, is that of the passage of the Alps by the Grand St. Bernard, by Napoleon, in May, 1800.*

Whenever the operations of an army are to be conducted in a country so mountainous and broken as to render it difficult or impracticable for ordinary field artillery to accompany the march and support the movements of the troops, recourse must be had to guns of less weight, and to lighter loads of ammunition, than those usually employed; and it may be necessary that the number of guns, in proportion to the troops, should be reduced also. This first degree of change is that which is required when the country is still of a character to permit the use of wheel carriages by the inhabitants, for in that case roads of some kind will be found to exist; and under such circumstances, provided that these roads are sufficiently numerous and practicable, the changes of equipment may be limited,—firstly, to the employment of ordnance not exceeding in weight 6 cwt., with corresponding loads of ammunition; and, secondly, to the reduction of the track of the wheels to a dimension within that of the country,† and of their height to a quantity that does not materially exceed the track. It will be necessary also that the draught be arranged to be readily made single or double, as required, and that draught mules with horse leaders should, if possible, be provided.‡

Under circumstances of sudden or expeditionary service, in a difficult country, but not wholly impassable to artillery, it may sometimes be convenient to convey the guns only upon wheels, and to carry the whole of the ammunition, excepting that on the

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* *Vide* Gassendi, 'Aide-Mémoire de l'Artillerie,' 1819, p. 265; and Thiers, 'Histoire du Consulât et de l'Empire,' Book iv.

† In most of the mountainous countries of Europe, the track of the country roads is from 3 feet 6 inches to 4 feet 8 inches.

‡ Such light batteries on a narrow track were employed by the British artillery in the early campaigns of the Peninsula on the frontier of Portugal; and the Service possesses, besides the light 3-pounders of 4 feet for colonial service, two descriptions of carriages for light 6-pounder and 12-pounder howitzers for the use of the Navy when acting on shore; in one of which the track (measured from out to out) is 4 feet 2 inches, and the wheel in height the same: in the other, for 12-pounder howitzers, now the established pattern, the track is 3 feet 8 inches, and the wheel 3 feet 6 inches. Spain possesses 4-pounder field batteries, constructed for narrow mountainous roads (*à carril estrecho*), with mules in double draught, that are capable of good service; and France had formerly similar equipments also; but since the rejection of the calibres of 4 and 6 pounders from her system, and the adoption of the mountain howitzer, properly so called, carried on mules, they have been entirely disused. For a detail of the various arrangements in the French Service for guns and carriages on narrow tracks or sledges, or other means of conveyance by men or cattle, which preceded in France the present system of Mountain Artillery, see Gassendi, 'Aide-Mémoire,' 1819, p. 303; and for a notice of the gradual progress by which the organisation now established was arrived at, 'Journal des Armes Spéciales,' 1842, ix. p. 397.

limber (if the latter be not also dispensed with), on pack-saddles. This would require nearly twice the number of cattle necessary to transport the same quantity in draught, but the equipment would be much more moveable, and able to master far greater difficulties than if the ammunition were carried on wheels.*

If, however, the country on which the operations are to be conducted be really mountainous, the roads practicable for any kind of carriage will be few and difficult, easily rendered impassable, and the movements of an army to which an artillery, modified even as above stated, may be attached, will be liable to be continually restricted and impeded by the embarrassment that it must of necessity occasion. Under the condition, then, of a country really mountainous, and when the question is that of operations, whether of attack or defence, and not merely of passage, all transport upon wheels must be abandoned, and the mule and pack-saddle become the resource of the artillery; the condition under which the weight of the guns to be carried, and all other loads of ammunition or equipment, being the capacity of that animal as a beast of burden, keeping pace with infantry in difficult ground. This may be considered to be at the maximum 280 lbs. exclusive of the pack-saddle. The mules for the service of mountain artillery should not exceed in height 14½ to 15 hands, and should not be taken from a level country, but, on the contrary, should have been accustomed to all the difficulties of mountain paths.

It is under such circumstances that the distinctive character of mountain artillery, properly so called, has its origin; and if, on the one hand, it should appear that the power of the arm is reduced, its mobility and ready application are entirely restored, and its quantity may be increased to any proportion that is thought fit: it need occasion no embarrassment whatever; for wherever troops can act, mountain artillery, properly equipped, may accompany them, and may make up, by its power of concentration and the mass of fire it may be employed to throw on the few points of operation that occur in mountain warfare, for its comparative inferiority of individual effect. For let it be remembered, supposing howitzers to be employed, and the calibre not to be less than 12-pounders, that apart from the consideration of the force of the blow of the projectile, which, however, is sufficient to destroy men and horses, the splinters of the shells have the same effect, whatever be the weight of the ordnance they are discharged from, and whether that be 2½ or 10 cwt.

It is necessary to observe, that the same conditions which present themselves to modify the equipments and service of the artillery in a mountainous country, produce also their effect on the system and character of the operations of the army. Not field artillery only, but cavalry also, are rendered almost wholly useless,—the order of the infantry changes, and becomes less dense,—positions, in general, less continuous,—and attacks in mass are replaced by others dependent on each other, and successive, but in smaller force;—surprises, the attack and defence of defiles, and movements by a flank, become frequent, and the whole character of the operations changes with that of the ground. To this change there is no reason that a mountain artillery, well organized, may not adapt itself with undoubted advantage: its function will, it is true, be considerably altered, but services of great importance will remain to it, provided that it be well equipped,—that it be rendered as moveable as the troops themselves,—that it never becomes a cause of impediment or delay,—and that its fire be capable of concentration in quantity, when required.

* The Austrian Horse Artillery formerly carried a part of their ammunition (80 rounds per gun for 6-pounders) on pack-horses. *Vide* Scharnhorst, 'Handbuch der Artillerie,' 1806, II. 300 and 547. The limber boxes of the 12-pounder field howitzer for Naval Service are fitted to be carried on the pack-saddle, when required.

In times past, the guns that from an early date were employed in Europe in mountain warfare, were carried upon mules, and consisted generally of 1 and 2 to 4-pounders inclusive, to which sometimes were added wall-pieces, and at a later period howitzers and mortars of reduced weight. More recently, by a change that seems to have obtained general consent throughout Europe, the small round-shot guns have been wholly abandoned, and have been replaced by light howitzers of 12-pounder calibre, formed into batteries regularly organized, and consisting usually of six pieces.

The mountain guns of the Duke of Wellington's army, which entered the Pyrenees in 1813, consisted of 4-pounders, and were Spanish guns: 3-pounders and light $4\frac{2}{5}$-inch howitzers had also been employed, and the British Artillery in Sicily were provided with howitzers of the latter calibre, of the weight of $2\frac{1}{2}$ cwt., on a low carriage or bed without wheels, adapted to be carried on mules; and of this calibre and construction two batteries were organized on the north coast of Spain, in 1836.*

In 1822, the French Artillery began a series of experiments on mountain guns, which ended in the final adoption, in 1828, of a 12-pounder howitzer of 6·22 calibres length of bore, and of the weight of 100 kils. (220 lbs. E.): the charge employed is ·27 kil. ($9\frac{1}{2}$ oz. E.): it ranges with 2° of elevation about 440 yards, and with 4° about 720. The extreme range extends to 1200 or 1300 yards. Its fire of common case is effective at 275 yards, but it will reach to 440 yards, and at this distance the balls pass through an inch deal. With spherical case the effect is good at 770 yards, and is still destructive at 1000. The penetration of the common shell in earth, at 440 yards, is $17\frac{1}{2}$ inches; at 880 yards, 12 inches; and it furnishes on the average seventeen splinters.†

Spain adopted, in 1837, without any material change, the French system; the howitzer and carriage being the same, with some trifling variations in weight that will be seen below. The principal difference is, that while the French mountain howitzer is occasionally in draught, when the ground permits, by means of a pair of shafts that fit to the trail, the Spanish Artillery do not employ that means of transport at all.‡ They likewise have adopted a pack-saddle of their own, somewhat heavy and bulky, but a very good one; and we have it on the authority of the British Officers who were attached to their armies during the late civil war, that their mountain guns constantly accompanied the division to which they were attached, over all descriptions of ground, without causing delay or embarrassment of any kind, frequently making good, daily, marches of from 8 to 12 Spanish leagues without

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* These carriages permitted the howitzer to be elevated to 32°, and appear to have been designed for considerable elevations rather than for horizontal fire. They are too low to clear the ground in their front, and have other disadvantages.

† 'Aide-Mémoire de l'Artillerie,' 1844, pp. 411-437.

‡ This pair of shafts in the French Service weighs $28\frac{1}{2}$ lbs., and must be carried when not used for draught. The English mountain 3-pounder gun is provided with a similar arrangement. It appears to be a good deal in use in Africa, where much of the country is level (Mémorial de l'Artillerie,' 1843, v. 57): but the resource seems hardly to be necessary in other countries; for whenever mountain artillery descends into the plains, carriages will assuredly be found, and there can be no difficulty in procuring such as may carry easily the guns and carriages of a mountain battery, and the whole of the ammunition, if necessary. It seems needless, therefore, to be embarrassed with the means of draught in the battery itself; more especially since very few mules indeed will be found capable of the double function of carrying and drawing; and to this should be added the consideration that the footing of a mule customarily employed in draught cannot be depended on with a load in difficult ground. In the mountains, therefore, the draught mules will be idle, or can only carry a moderate load of forage or other supplies, and will not be available for the general service of the battery.

difficulty, with less distress to the cattle than to the horses of the cavalry, and, above all, without sore backs.* Lieut.-Colonel De Salas, of the Spanish Artillery, in a little work, printed in 1844,† further supplies the fact, that in two years, ending in June, 1841, during a considerable portion of which the operations were most active, the loss of mules by death and being rendered unserviceable in five mountain batteries of 70 mules each, amounted, under all the disadvantages of a first essay, and with general inexperience, only to 61, being at the rate of $8\frac{7}{7}$ per cent. per annum.

These results, and the experience of the French in Africa since 1830, afford proof that must be deemed conclusive, both as to the efficiency in respect to movement, and the good service of the artillery in question.‡ And in France this consequence seems to have been arrived at—the total disuse of all ordnance between the mountain howitzer of 100 kilogrammes and the 8-pounder gun and 24-pounder howitzers of their field batteries, of 580 kilogrammes (11 cwt.)§

In 1838 the French Artillery added to their materiel applicable to mountain service a small mortar of 15·13 centimetres calibre (24-pounder, or 6-inch), in weight 70 kilogrammes (154 lbs.), which, with a charge ·14 kil. (4·9 oz. E.), ranges at 45° to about 660 yards, and at 15° to 385 : the chamber will contain $7\frac{1}{2}$ oz. The British Artillery possesses mortars of $4\frac{2}{5}$ and $5\frac{1}{2}$ inches calibre (12 and 24 pounders), in weight 102 and 158 lbs., and capable therefore of being carried on mules. They have frequently been employed with good effect, and require but amall charges : the penetration of the shell, however, is but trifling, and a mortar of larger calibre, say 32-pounder, or even higher, which should still be within the limit of transport on the pack-saddle, appears to be desirable.

In considering the subject of mountain artillery it will be proper to notice a weapon that, from various causes, has not yet arrived in military estimation at a fixed or due value—the rocket. In circumstances that render the application of other means impossible it may be availed of, and in many cases, with advantage. One of the qualities it possesses is that of a portability so complete as to render all positions accessible to it ; and in some respects it has advantages, as, for example, in retreat, over the mountain howitzer. In the enfilade of a bridge, a ditch, a high road, or intrenchment, it is without doubt capable of proving a very effective weapon. It has also a power of penetration which is very considerable, and that, when it has attained nearly its maximum velocity, is at least double in earth that of round shot of the same weight with a full charge. Its maximum velocity being, however, considerably less than that of shot, it is not well suited to make impression on hard substances, though probably quite capable of effecting a breach in brick-work, at a proper distance. In long tubes and in calm weather, at 1000 yards, the 12-pounder rocket hits very nearly as well as a field howitzer, and penetrates in earth more than 12 feet.

To the ordinary service, however, of a country over which artillery on wheels cannot pass, the lighter rockets, 6 and 3 pounders, appear to be those best suited. Of the last, a mule carries easily fifty-six rounds, with all the necessary equipment ; the weight of the load, exclusive of the saddle, being 276 lbs. ; and this calibre may be used on the march for the enfilade of hedges or other cover, from a flank in oblique fire, or to protect a retreat, carried in the hand, and halting only to fire. Of

* Of four marches in Aragon and the adjacent provinces, in 1838-9, amounting to 273 leagues in 33 days, each march performed without a halt, the shortest of which was 62 leagues in 7 days, and the longest 76 in 9 days, the day's march varying from 5 to 12 leagues, and the league fully equal to 3 English miles, the average distance daily was 8·28 leagues, or 24·84 English miles.

† 'Tactica de Artilleria de Montaña a Lomo,' 18mo, Madrid, 1844.

‡ 'Mémorial de l'Artillerie,' iv. 14, and v. 8.

§ The 4 pounder field gun was finally suppressed in 1841.—'Mém. de l'Art.' v. 42.

6-pounder rockets, a mule may carry twenty-four rounds; but the sticks, from their length (7 feet) render the load inconvenient; and an improvement of construction is desirable. No fire, it is well known, is capable of a repetition so rapid as that of the rocket, and little is wanting to give this weapon a very important application in mountain warfare but the means of rendering it accurate in direction.

The establishment of the Mountain Batteries of Spain, as determined by Royal Order, February 18, 1844, is as follows.

12-pounder howitzers.	Rounds per gun.	Total Number of Rounds.	Officers.	Non-commissioned Officers, Trumpeters, Artificers, and Gunners.	Riding-horses for Non-commissioned Officers and Farriers.	Pack Mules.	
6	80	480	5	115	6	55	The horses of the Officers are not included.

One fourth of the ammunition is case-shot. One ammunition mule only marches with each howitzer when ready for action,—making, with those carrying the howitzers and carriages, 18 mules per battery, each mule being conducted by an artillery-man. Eight non-commissioned officers and men are attached to each howitzer for its service,—to load and unload it and the carriage, and to supply ammunition while in action. The rest of the mules are considered as reserve, and are in the charge of artillery-men, one man having the care of two mules. They act as muleteers.

The mules are distributed as follows:

	Mules.
6 subdivisions of 3 mules each, carrying the howitzer, the carriage, and 1 pair of ammunition boxes, containing 16 rounds per gun and 96 per battery .	18
24 loads of reserve ammunition, 384 rounds per battery	24
For stores, tools, and forage.	7
Spare howitzer carriage	1
Spare mules (unsaddled)	2
For officers' baggage.	3
Total	55*

The French Mountain Batteries, consisting also of six 12-pounder howitzers, carry 165 rounds per howitzer, of which 20 rounds are common case and a portion spherical case,—making 990 rounds per battery. Each battery has 100 mules; but in this number are included 15 for the transport of infantry ammunition (30,000 rounds), also 2 mules spare.† The establishment of non-commissioned officers and men is not stated. When first formed, the French Mountain Batteries of six howitzers carried 80 rounds per howitzer, and had attached 4 officers, 70 non-commissioned officers, artificers, and artillery-men, 11 riding and 74 pack mules, of which 9 were spare, the cattle being led and looked after by 47 conductors, who

* 'Tactica de Artilleria de Montaña,' Madrid, 1844.

† 'Aide-Mémoire,' 1844, p. 287. So small an allowance of spare mules in the French and Spanish Batteries can only serve when the means of replacing losses or casualties to cattle are immediately at hand.

were either muleteers or soldiers of the Train. The total number of persons, therefore, exclusive of officers, was 117. At this period the knapsacks of the men were carried on mules, 12 being assigned for the purpose;* but the arrangement appears now to be discontinued.

The English Mountain Batteries on the north coast of Spain, from 1836 to 1840, consisted of four $4\frac{2}{5}$-inch or 12-pounder howitzers carrying 96 rounds per gun, and there were attached 3 officers, with 60 non-commissioned officers and men, and 9 Spanish muleteers, 3 riding and 36 pack mules. The battery was divided into front and reserve, and there marched with the former, when ready for action, 2 ammunition mules per howitzer, carrying 48 rounds,—making, with those carrying the howitzers and their carriages, 14 mules and 192 rounds.

In the Establishments of the French and Spanish Batteries, it will be perceived that the total quantity of ammunition carried being as 2 to 1 nearly, the French battery averages more than $11\frac{1}{2}$ rounds per mule, and the Spanish not quite $8\frac{3}{4}$ rounds, the package of ammunition being the same. The proportion of 80 rounds per howitzer in the Spanish Service is obviously too small. It ought at least to be 120 to 150 rounds per howitzer.

The comparative weights of the principal articles carried in the batteries of the three countries mentioned, reduced to English weights, are as follows:

	The Howitzer.	The Carriage.	A pair of Ammunition Boxes packed.	The Pack-Saddle.	
				For Gun or Carriage.	For Ammunition.
	lbs.	lbs.	lbs.	lbs.	lbs.
France .	220	243	216	48	48
Spain . .	208	265	219	86	70
England .	280	105	330	41	45

The English carriages, as has been stated, were without wheels. Exclusive therefore of side-arms, shafts, &c., and without forage, the greatest load of the French battery, saddle included, does not exceed 291 lbs.; of the Spanish, 351 lbs.; and of the English, 375 lbs. But the mule of the French and Spanish batteries carries only 16 rounds, and the English 24, of which half are spherical case,—a load which certainly is excessive, and should be reduced, say to 20, or, perhaps, to 18 rounds. The weight of the English howitzer is also greater than it ought to be, by 30 or 40 lbs.: and it is too short as well as too heavy. An advantage of some importance was, however, afforded to the mule which carried it, by placing the howitzer across the back, in a saddle constructed for the purpose, instead of in the direction of the animal's length. By this means the centre of gravity was lowered several inches, and greater facility was afforded likewise for unloading and loading the mule in going into or out of action. Three men, with some little practice, were able readily to place the howitzer in the saddle or to unload it; though the weight, at the height of the eyes, of a man of good stature, was upwards of 90 lbs. to each. The carriages being without wheels, two of them were carried easily by one mule, together with a small assortment of intrenching tools,—the whole load, saddle included, being 303 lbs.

The construction and dimensions of the French and Spanish mountain batteries

* 'Aide-Mémoire Portatif,' 18mo, Strasbourg, 1831, p. 88.

differ but little from each other, excepting in the pack-saddle,—that of Spain deserving the preference, though it would seem possible in this, for the howitzer, to improve the framing of the tree, and to reduce the weight. It is the 'Bât à la Catalane' of the French.

The height of the French wheel, in English measure, is 37·6 inches, its weight 51·8 lbs., and the span, from out to out, 31·3 inches. The height of the Spanish wheel is 37·1 inches, and its weight 59·3 lbs. English.

The recoil of the mountain howitzer is violent, and requires that both wheels should be dragged: this is effected by means of a rope passed from wheel to wheel, the ends being brought together above the block of the trail. Unrestrained, the recoil would reach to 36 feet.*

The drawings annexed of the Spanish mountain howitzer and its equipment are from the 'Tactica' of De Salas, already quoted, and will afford an idea of its character in both Services. (See Plates of 'Mountain Artillery.')

The saddle for the howitzer is fitted for either howitzer or carriage, and an iron pin (*pinzote*) is attached to the framing of the tree on each side, upon which, when on the march, the wheels may be carried separately from the body of the carriage, and the centre of gravity of the load much lowered. When not wanted, these pins fold sideways upon the saddle.

The French batteries carry with them a portable forge, for which one mule is allowed, and six men for the conveyance of other tools, materials and stores. The forge is the same as that attached to regiments of cavalry, and its total weight, with tools complete, and 24 lbs. of charcoal in a leathern sack, is 188 lbs. English.† In the Spanish batteries the forge is dispensed with, and three mules appropriated to spare shoes, materials, and tools.

Without doubt the mule is the best animal of burden possible for the use of artillery in a mountainous country: hardy and powerful, yet capable of subsisting on little and coarse food, he is liable to few disorders, sustains easily great changes of temperature, and, above all, is possessed of an instinct or judgment in the choice of his footing, when heavily loaded and in difficult ground, superior to that of all other animals, and by that means is able to pass safely where none else could do so. And in pace and in endurance he is equal to the utmost effort that can be made by any infantry whatever. In case of necessity, however, the horse of a mountainous country, (usually compact, small-boned, and of moderate size), where accustomed to carry burdens, may to a certain extent supply the place of the mule, but not to advantage in comparison, or to the same quantity of load.‡

In Asia and Africa, the camel is often employed to carry guns of light calibre, and the power of this animal as to burden is considerably above that of the mule. But his pace is slow; he belongs especially to the plains and to the desert, and is totally unsuited to the mountains and to slippery ground.§

Among the means of transporting artillery in mountainous countries,—the former resource of infirm travellers,—the litter, carried between two horses or mules, which is still in use in some countries, has been proposed; but it is not properly a mountain equipment, and can only be made use of where the ground is gradual in ascent, or

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* 'Aide-Mémoire de l'Artillerie,' 1844, p. 411. † Ibid. p. 326.

‡ In Cornwall, Devonshire, and Wales, and in many of the mountainous parts of England, where the paths are steep and few roads exist, pack-horses are still employed; and in certain of the mining districts mules also are used for the conveyance of ores.

§ The Turkish army, 1840-1841, carried 12-pounder field howitzers of the weight of about 5 cwt. on camels, from the coast to Jerusalem; but, though the ground was not of a difficult character for mules, the camels suffered severely, and many were destroyed.

descent, the turnings easy, and the distance not considerable. The extent of the load, at the utmost, with two very good mules, is about 450 lbs.; and in a descent that is at all precipitous, the front mule is very liable to fall, and to be severely injured.

In the French Service the first reserve of infantry ammunition is attached to their mountain batteries, as it is to their field batteries in the plains; but in an English army this arrangement is not likely to be followed. The proportion attached to the French mountain batteries is 30,000 rounds, carried by fifteen mules, of which five march with the front of the battery, and ten with the reserve. In the British Service the mules of the first reserve of ammunition will probably be attached to the brigades of infantry, as formerly, and will march in their charge.

Little has been written on the subject of Mountain Artillery in its present form that may serve as a guide in service, beyond what is contained in the Aides-Mémoires, and the authorities quoted; and experience is yet wanting to indicate with precision the rules of tactique according to which it should be employed. Decker* makes some important observations on the service of artillery in a mountainous country, but enters only briefly into the question of continued operations. Jomini, in the article 'De la Stratégie dans les Montagnes,'† presents the general conditions of offensive and defensive war in relation to the principal mountainous countries of Europe, but chiefly as to the operations of passage, and without reference to the use of artillery; nor does he in the short but important article 'De l'Emploi de l'Artillerie,'‡ in the conclusion of his work, make any observation on its service in the mountains. In a word, the tactique of mountain artillery, necessarily dependent on that of the infantry, has yet to be created; and since this last must vary with the nature of the country (for all mountains are not alike), with its resources, with the character of the inhabitants and their relation to the contending armies, as well as with that of the troops employed, it would seem to follow, that in respect to mountain warfare, general principles only can be asserted,—that no system can be prescribed; and, in the words of Jomini, that 'c'est dans l'étude des faits que l'on peut reconnaître *toute la vanité de théories de detail*, et s'assurer q'une volonté forte et héroïque peut, dans la guerre des montagnes principalement, plus que tous les préceptes du monde.'§

But in whatever manner operations may be conducted, certain general principles, results of experience, and precautions, will be useful; and the following precepts have been thrown together, not in the pretension of being complete, but that they may serve to remind an officer in command of a mountain battery of some of the points to which his attention should be directed.

Examine by means of a mounted officer, or non-commissioned officer, the paths in advance in the line of march and around, as far as practicable, and procure information from the inhabitants whose fidelity can be relied on; but in a difficult country trust to no one, either as to information or as a guide, that is not himself a muleteer or an accustomed traveller. The fatigue of cattle depends mainly on the choice of the path.

Avoid defiles and narrow passages as much as possible: in many countries the best paths are frequently along the ridge. One kind which occurs in a forest country it is necessary to be guarded against—it is that used by charcoal-burners, which is usually without an outlet. Employ tools and labour to improve a bad passage: this is better than to incur the risk of laming cattle.

Wherever practicable and proper to do so, take a different line of march from

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* 'Tracté Élémentaire d'Artillerie,' Book ii. art. 13, p. 410. Paris, 1825.

† 'Précis de l'Art de la Guerre,' art. 29, p. 330. Paris, 1837. ‡ Ibid. art. 46, p. 598.

§ Jomini, 'Précis de l'Art de la Guerre,' p. 342.

the infantry, in order to allow the cattle to move at their natural pace, and avoid the embarrassment of frequent halts.

In difficult ground, do not permit the cattle to be hurried, but allow the mules to pick their own way freely, and at their own pace. It is best not to attempt to lead them, taking care only that they do not crowd upon each other. In forests that are closely timbered, it will be necessary, perhaps, to lead, in order to prevent the derangement of the load by striking the trees, or against each other.

In very difficult and precipitous ground, it will sometimes be advisable to transport the howitzers and their equipment wholly by men; and if proper arrangements are made, this is by no means a difficult matter, and may save much time; it being possible to convey by hand, either in ascent or descent, the materiel of the batteries over ground that no mule can pass at all,—the cattle in such case making a détour.

The best positions for mountain artillery are those from which all around can be seen, but which have only a moderate command, the fire becoming inaccurate when the angle of depression is considerable, and the projectile does not gravitate upon the charge. In many cases, the incurvated track of the shell and its moderate velocity, which does not usually permit it to lodge, will be found to lend itself favourably to the character of the ground, particularly when the circumstances of the enemy's position can be observed from a flank.

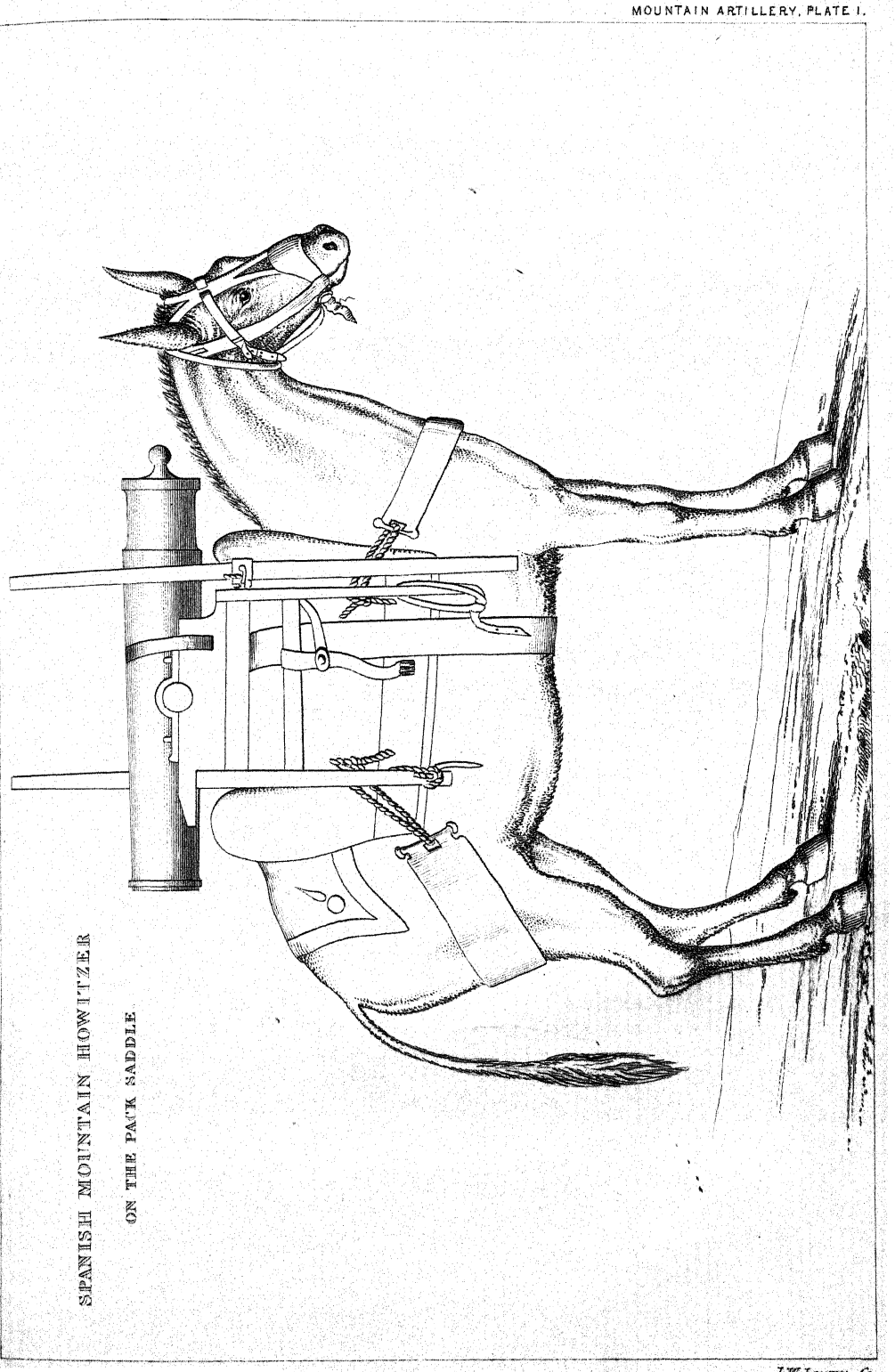
Take care, on coming into a position, that it has both an outlet and an entrance; and if necessary, make one: time may otherwise be lost in moving in advance; and in case of retiring, the batteries may occasion delay to the troops, and be exposed to impediments.

Examine well the confluence of valleys and all the paths which converge or issue from them; and take care, as far as possible, to command them. Obtain the enfilade of a communication, of a position, of cover, or of a probable deployment, whenever possible, and if not, an oblique fire. If the enemy be intrenched, and has the hill above him, direct on it shells with long fuzes, and let them roll into the trenches. This will oblige him to seek security by means of a counter-ditch, and the existence of this precaution will show the ground he intends to dispute. If houses are occupied by the enemy, the walls will resist the fire of the mountain howitzer, unless formed of slight materials; but roofs in general are easily penetrated. Occasionally high angles of elevation may be useful, and the shells may be partly filled with lead to give them penetration. When this kind of fire is employed, it will be proper to maintain the elevation constant, and to vary the quantity of powder. Charges may be weighed and assorted beforehand, so as to admit of being adjusted by small additions, without delay.

As a general rule, economize ammunition to the utmost, and avoid all desultory firing without an object; but be prepared to open and concentrate your fire, and if possible, that of several batteries, at a decisive moment, not by assembling them on the same ground, but by the convergence of their fire. Bring as few mules under fire as possible, relieving them as their ammunition is expended.

As in all other cases, the correct estimation of distance, and the precision of fire *on opening*, is of the utmost importance. Place on each flank an intelligent non-commissioned officer to watch and report the fuzes, and the effect of your fire. The moral effect of the fire of artillery is best produced by occasional pauses, when its effect is not important, by ascertaining the point on which it can be directed to most advantage, and then, having duly employed the interval in preparation, throwing in suddenly upon that point a well-directed and concentrated fire.

Discover, if possible, the enemy's object and method of attack, if he be the assailant, and throw in on the head of his columns a mass of fire, attending more particularly to the defiles through which he may have to pass. In a fixed position, avail yourself



SPANISH MOUNTAIN HOWITZER

ON THE PACK SADDLE

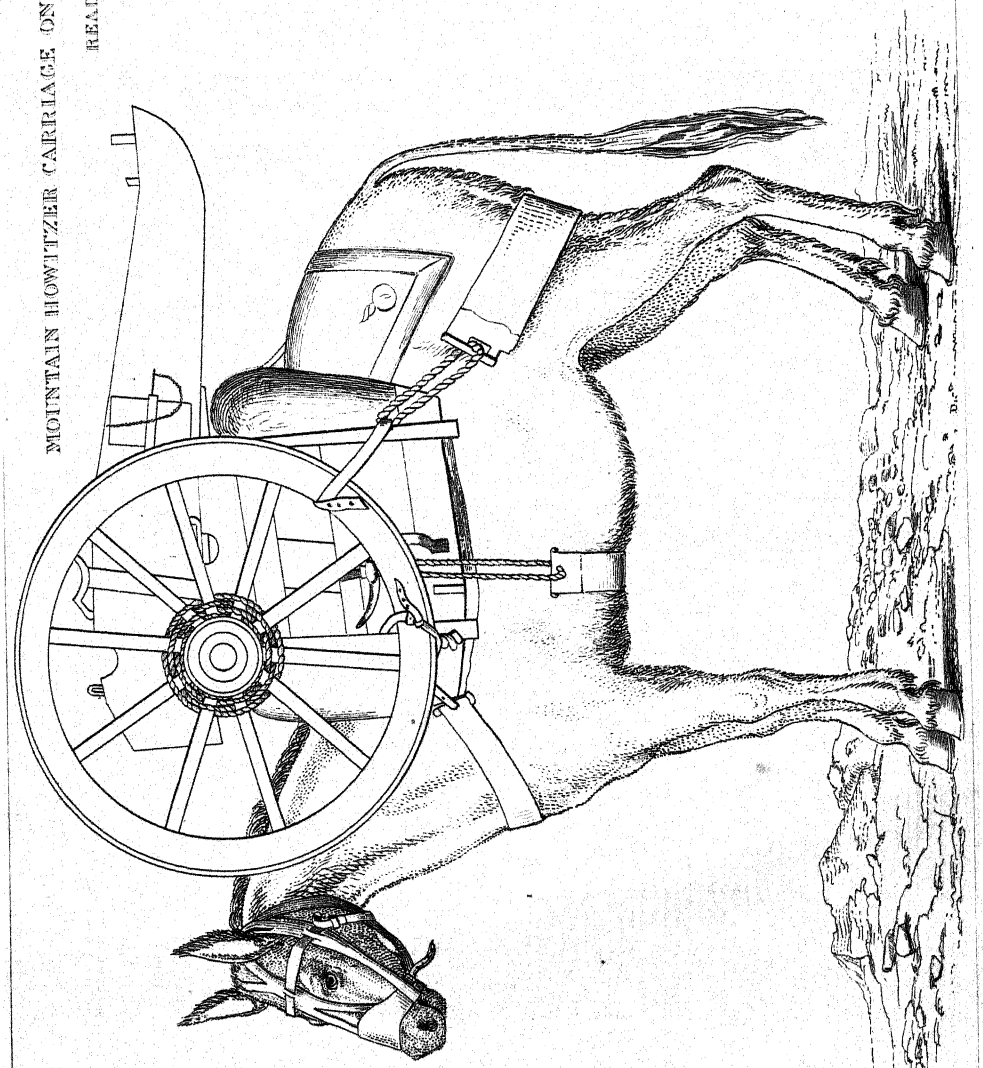
J.W.Lowry fc.

Published by John Weale, 59, High Holborn.



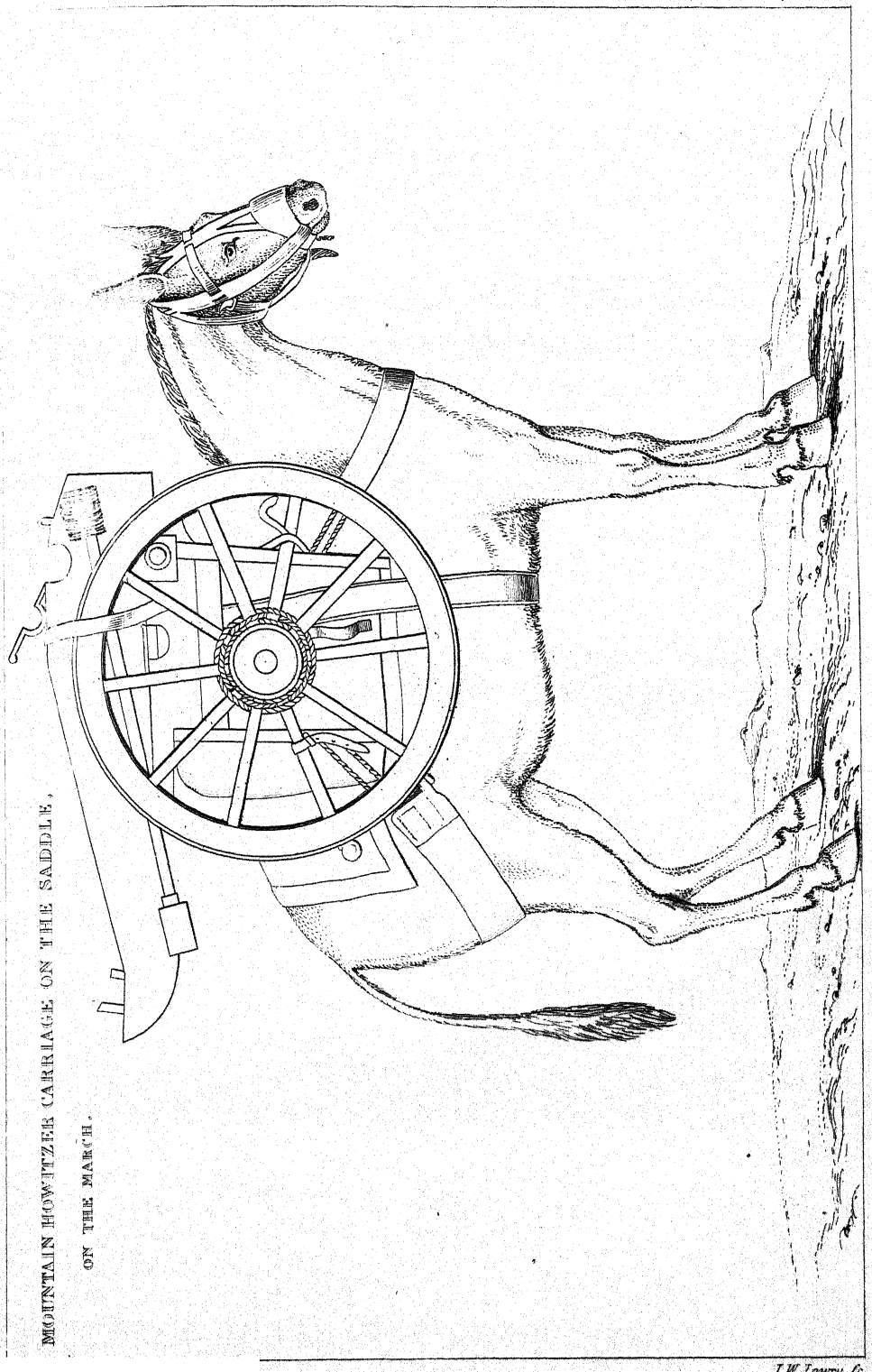
MOUNTAIN HOWITZER CARRIAGE ON THE SADDLE

READY FOR ACTION.



J. W. Lowry fc.

Published by John Weale, 59, High Holborn. 1849.



MOUNTAIN HOWITZER CARRIAGE ON THE SADDLE,

ON THE MARCH.

J.W. Lowry fc.

Published by John Weale, 59, High Holborn, 1849.

MOUNTAIN HOWITZER AMMUNITION BOXES.

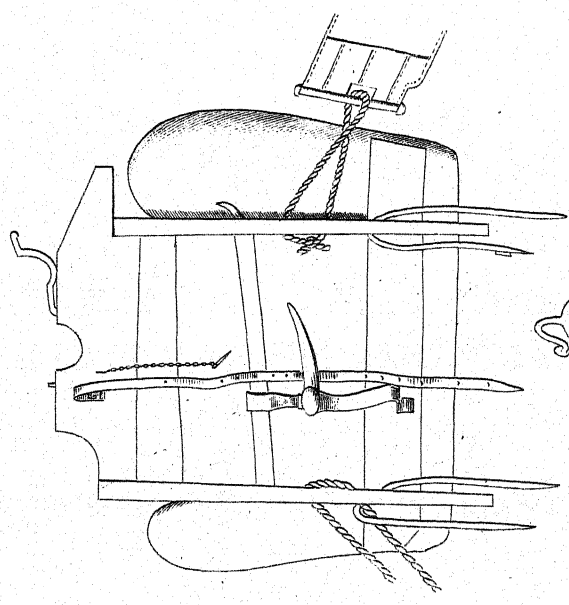
The bears on the March are covered by a Water deck not here shewn.

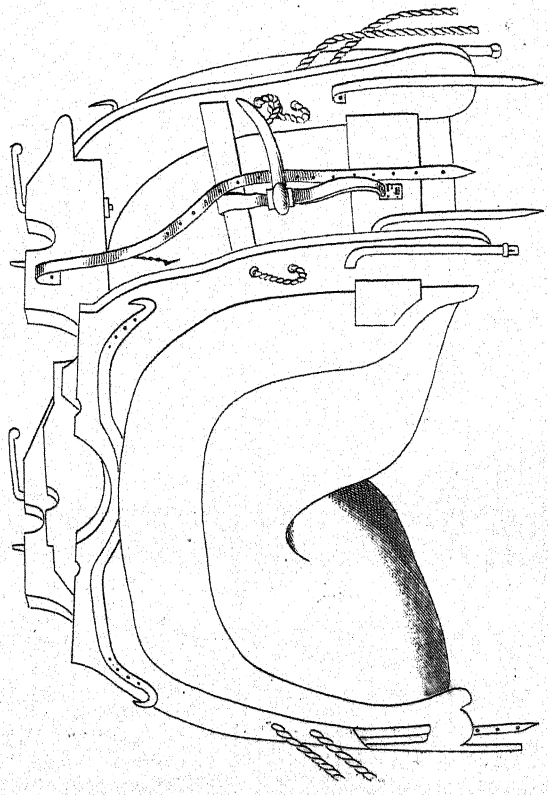
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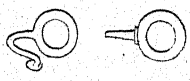
Published by John Weale, 59 High Holborn, 1849.

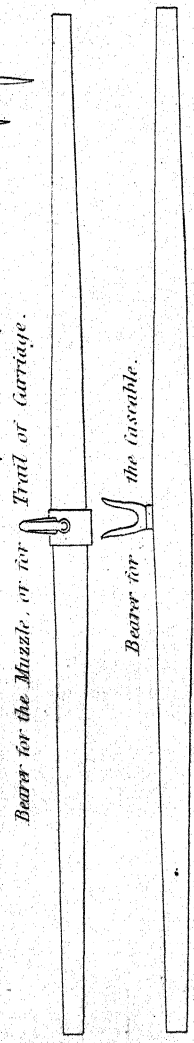


PACK SADDLE FOR MOUNTAIN HOWITZER ON CARRIAGE.









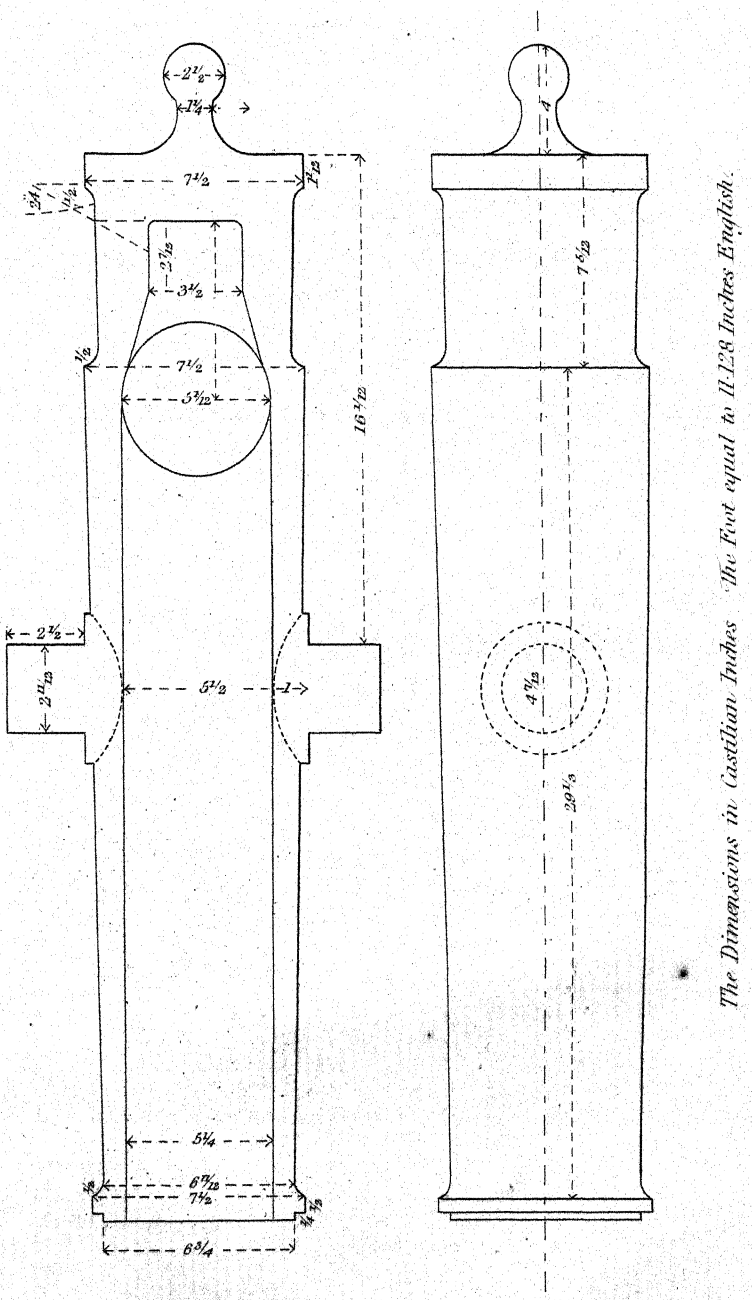
Bearer for the Muzzle, or for Trail of Carriage.

Bearer for the Cascable.

J.W. Lowry fc.

Published by John Weale, 59 High Holborn 1849.

SPANISH 12 Pr MOUNTAIN HOWITZER.



The Dimensions in Castilian Inches. The Foot equal to 11.128 Inches English.

J.W. Lowry fc.

Published by John Weale 59 High Holborn.

of every means of rendering it secure. If the attack be on your side, take care to choose ground that will enable you to support it to advantage, to concentrate your fire upon the points to be assailed, and to follow up success.

Great attention must be paid at all times to the equilibrium of the loads, but especially after ammunition has been expended.

Whenever a halt occurs of sufficient continuance, and circumstances permit it, let the cattle be unloaded, taking care, while halted, and whether loaded or unloaded, that they do not roll.

Carry at the least half a day's corn with each mule, but do not feed on the march, unless the halt is considerable. Do not usually carry more than one day or a day and a half's corn on the loaded mules; it is better, when necessary to carry forage, to have mules assigned for the purpose.

No baggage of any kind is at any time to be allowed to be placed on the mules of a mountain battery, excepting on those appropriated to the purpose, on pain of being cut off and abandoned. The men should carry their knapsacks, reduced to what is absolutely necessary, and their great coats. In the French service, the knapsacks were at first carried on mules, but this practice is discontinued.

Whenever the battery arrives on a plain where carriages of any kind are to be obtained, procure them, and the cattle necessary to convey the loads until the ground again changes.

Never unsaddle, when the march is over, in less than an hour and a half to two hours from the time of halting.

In some countries it is customary to place ammunition carried by mules in the church, where lights and fire are easily interdicted. This is usually a convenient arrangement, access, in general being easy on all sides; but care must be taken to secure the entrance, and that there be no impediment to turning out quickly when required. If infantry ammunition is also deposited in the church, a different entrance should be assigned to it. Marks to distinguish the cattle and their subdivisions are easily made by scissors in the hair of the off-side of the neck or rump, in numerals 4 to 5 inches high, and other marks may also be made in the hair of the tail by straight cuts across, a few inches below the root, to denote the battery to which the mules belong.

Allow no harshness to be employed towards the cattle without necessity, which can very rarely occur. The mule is far more obedient to the voice than to any means of punishment whatever, and though resentful, is much more sensible of good treatment and of attachment than generally supposed.

Great attention must be paid to shoeing, and to the condition of the feet: every mule must carry a fore and hind shoe fitted, and two sets of nails to each, and the farrier a full set. The Spanish and Turkish methods of shoeing are the best. In some countries mules work without being shod behind; and in ground where the rock is hard and smooth, this is of great importance, through the security it affords.

The utmost care is also to be given to the pack-saddles, which are to be fitted to every mule, and never changed but from necessity. If, notwithstanding all the care that can be taken, a gall should occur, the saddle must be eased at that point by thinning the stuffing, to remove the pressure.

This article cannot be more properly concluded than by stating, that whatever may be the efficiency a mountain artillery perfectly well organised may arrive at, the moment that the army quits the mountains to descend into the plain, the proper field artillery should be resumed; for of this arm it is assuredly true, that *the heaviest that can perform the movements required to accompany and support the troops is that which ought to be employed.*

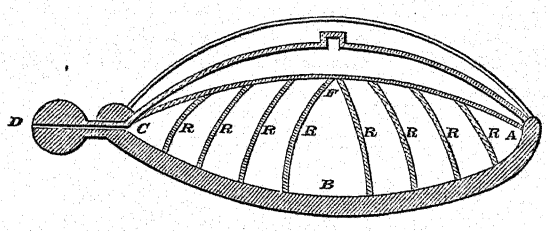
J. N. C.

MOUNTAIN BAROMETER.—Under the article BAROMETER, a description of the mercurial instrument was given, but the present pages are devoted to the *Aneroid Barometer*, of which the following description is given, previous to an explanation of some experiments which have been made to ascertain its value in measuring the heights of mountains not much exceeding 2000 feet.

ANEROID BAROMETER.*

"M. Conté, in his balloon ascents during the war in Egypt, found the ordinary barometer subject to so much oscillation that it was useless. He was the inventor of the Vacuum-vase, and the following is a copy of his instrument, and the description he gives of it, extracted from the 'Bulletin des Sciences,' Floreal, an 6, page 106.

Fig. 1.



"'M. Conté, Professor of the Aërostatical School at Meudon, near Paris, and now in Egypt, has occupied his attention for some time past in adapting a barometer which, although of simple contrivance, should be more sensitive than those already in use. We now proceed to explain the first of his discoveries. It is very like a pocket watch. (See fig. 1.) A B C is a bowl made of strong iron or copper, upon which is a cover, C F A, of a very thin sheet steel, and the edges of which must be fitted with great exactness. The springs, R R, keep the cover at its elevation; and while they regulate its action, the air is pumped out of the bowl, A F C B, through the opening at D. This opening shuts itself so as to be air-tight, and then the whole weight of the atmosphere forces down the flexible bowl, C F A. Now, as the resistance of the spring remains constantly the same, this cover-plate rises or falls as the atmospheric pressure varies; and these variations are shown by means of a hand, securely fastened, which passes backwards and forwards upon a divided plate.' The discoverer, however, acknowledges that he was compelled to reject this instrument, on account of the prejudicial influence which the change of temperature had upon it.

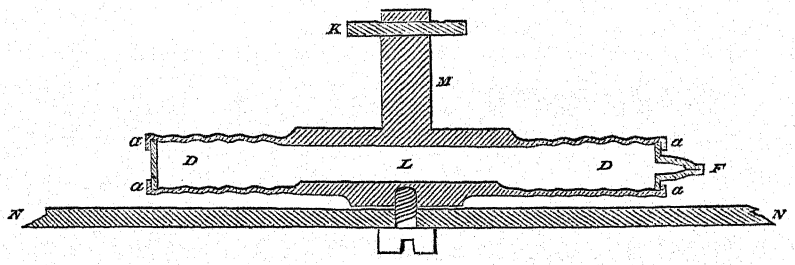
"From the above diagram, there may be adduced many strong reasons, besides that which M. Conté has stated, to show why he was not successful. The principal one would readily suggest itself to any person of mechanical information. The figure he chose as the object of atmospheric compression is, perhaps, of all forms, the worst adapted for that purpose; viz. an *arch*. That he has recorded the principle, cannot be disputed; but when we consider what has been stated relative to the form of his vacuum-vase, to say nothing of its inadequately small dimensions, we must be permitted to question if he ever obtained any practical result. The extreme ingenuity of M. Vidi, the inventor of the instrument about to be described, appears, then, to be in

* From a 'Treatise on the Aneroid,' by the late Edward J. Dent, F.R.A.S., &c. &c. &c.

no way disparaged by the claims to the invention of the principle which have been set up for M. Conté by his friends.

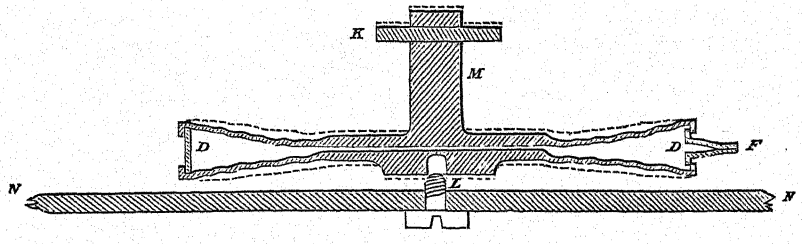
"A diagram and explanation of M. Conté's vacuum-vase having been given above, it will be proper to detach and exhibit on paper that of M. Vidi, that the difference between the two may be shewn more clearly, and that the ingenious means adopted by M. Vidi to correct for varying temperature may be the better appreciated.

Fig. 2.



"In fig. 2 the vacuum-vase is represented in the shape which it presents before it is exhausted by the air-pump : *a a a a* shew the turning or lapping over of the thin corrugated diaphragms where they are soldered to the rim ; D D is the vacuum-vase ; M is the socket, which, being pulled by the pin, K, places the vase in a state of tension, whereby it offers resistance to the pressure of the external atmosphere.

Fig. 3.



"Fig. 3 shews the vacuum-vase in a compressed state, after the air has been exhausted by the air-pump, through the tube, F. The dotted lines, running nearly even with the corrugated surface, are intended to shew the position which that surface will assume after the introduction of the gas, which effects a compensation for the results of varying temperature.

"From the circumstance of a gas being (perhaps for the first time) introduced into an instrument with a view to effect a correction for variable temperatures, and from its being an invisible agent, a short explanation may be required in verification of its being adequate to produce the results asserted. Such an explanation will serve to impress on the attention of those who study mechanical science, how important it becomes to take into their consideration, not only the expansion of metals upon an increase of temperature, but also the loss of elastic force, to which in a state of tension, they become subject. The student is familiar with tables indicating the expansion of metals ; but, even at the present time, no table has been calculated in order to shew the loss sustained by elastic bodies when in a state of tension : perhaps no instrument, although made for the express purpose, could exhibit an experiment

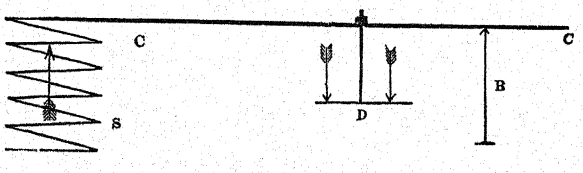
more satisfactory for the proof of this point than the aneroid. We are enabled to use it as a pyrometer by applying the heat of a lighted taper to the spring S, figs. 4, 5, without communicating that heat to the vacuum-vase. A table of direct expansion would cause us to conclude, that as the spring S would, on being heated, become longer, it would raise the lever C higher; but the experiment above adverted to produces a contrary result, (for the spring, S, losing its elastic power through heat, is forced down by the atmospheric pressure on the vacuum-vase), and proves that the loss of elastic force is greater than that of direct expansion. The hand of the aneroid indicates this, by moving towards the right, or 'set fair.'

"We might further suppose that an increase of heat, expanding the metal of which the vacuum-vase was made, would proportionately increase its capacity; whereas the contrary is actually the case;—a conclusion which is proved by heating the vacuum-vase alone. It must be admitted that the metal diaphragms have become both larger and weaker by an increase of temperature, whence the capacity of the vacuum-vase would be rendered greater; but it must be also remembered that the atmospheric pressure on the surfaces, amounting to a force of 44 lbs., brings the upper and lower diaphragms, thus weakened by heat, closer together, so that the cavity of the vacuum-vase has, in fact, become smaller.

"This brings us to the subject of compensation accomplished by gas. On the capacity of the vacuum-vase being diminished by heat, as has just been shewn, the gas contained within it is, by the same cause, expanded; and, resisting the compressing force of the atmospheric weight upon the diaphragms, keeps them separated at a due distance, and effects the compensation.

"The vacuum-vase is brought into a state of tension by separating the diaphragms, after exhaustion, and placing the pin K on the lever C, as shewn in fig. 5. The lever C is then to be placed on its fulcrums, B B, and the other end of the lever C to rest on the top of the spiral spring S. The action of the atmosphere on the vacuum-vase, and the connection of the latter with the spring S, require to be clearly understood, in order to a perfect acquaintance with the principle of the aneroid. To illustrate this still further, it appears necessary to give a diagram explanatory of the theorem.

Fig. 4.

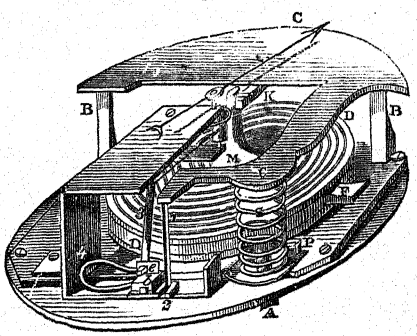


"D represents the vacuum-vase. The arrows indicate the downward pressure of the atmosphere, which alone keeps the lever C on its fulcrum B, as well as on the *top* of the spring S. This spring is compressed by the atmospheric force on the vase; whence it will be seen, that if the vacuum were destroyed in the vase, the lever C would instantly fall off its fulcrum, as well as off the top of the spring S. The lever C, it may be remarked, is of the second order.

"Let us suppose an increase of atmospheric pressure on the vacuum-vase to take place; the fulcrum B would remain, of course, firm and unaffected. The surface of the vase D would be forced downwards, and the spring S, at the same instant, still more so, as must be apparent from considering the increased distance of the lever, which in the aneroid is as six to one.

"A few words may be required for the further illustration of this subject. We know that the atmospheric pressure is about 15 lbs. to the square inch. Now the vacuum-vase being 2½ inches in diameter, this surface gives for its product a pressure of about 73 lbs. on the vase; though, from many causes, this amount of atmospheric pressure is considerably reduced.

Fig. 5.



In order to ascertain the actual weight produced by the atmosphere upon the surface of the vacuum-vase, recourse was had to an experiment affording positive demonstration. The hook of a steel-yard, or spring weighing-machine, was attached to the upper part of the vase by the pin K (fig. 5), and, on being pulled up to the point parallel to the top of the vase, shewed the weight of 44 lbs.; which is, therefore, proved to be the force by which the lever C is kept on its fulcrums B B, and on the top of the spring S.

"It is hoped that the principle of the aneroid has, from the foregoing explanations, been made sufficiently intelligible; and, if so, it will be an easy task to describe the remainder of the mechanism. We will now refer to the perspective drawing of the interior of the machine: D D, vacuum-vase; C C, lever, to the end of which is attached a vertical *rod* (1), which merely serves to connect the lever C C with the levers (2 and 3). These levers are connected by a bow-piece (4). The two square-headed screws at *e b* admit by screwing or unscrewing them, such an alteration of the distance of leverage as to allow the hand of the aneroid to move over a space corresponding with the scale of a standard mercurial barometer. To the end of the lever (3) is attached a light rod, terminating with a piece of fine watch-chain, which is attached to a small roller. On the axis of this roller the hand of the aneroid is firmly fixed, and kept in its position by means of a flat spiral spring, the outer coil of which is seen attached to the axis. This flat spiral spring, which is always in a state of tension, maintains a pressure against the force of the levers, and keeps the hand of the aneroid in obedience to the indications of the vacuum-vase. Were it not for this spring, the hand *b*, fig. 6, would remain stationary at the point to which it had been propelled.

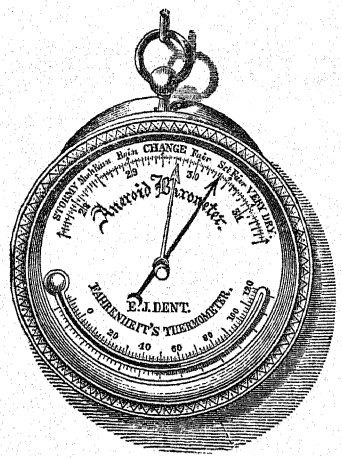
"*To set the hand of the aneroid to correspond with any other barometer.*—A, the head of the screw, figs. 5 and 6, to be considered as at the back of the case. This screw A, when screwed or unscrewed, alters the position of the hand, *and is not to be touched for any other purpose.* It acts in a piece of brass, seen at P in fig. 5, which is prevented from turning round the spring S by means of a pin inserted in the plate. When the screw A is moved, it raises or depresses the lever C C, whence motion is communicated to the hand.

"*To register the variations of the aneroid.*—A nut, as seen at O, fig. 6, projects through the centre of the glass, to enable the observer to move the gilt index beneath it. By this gilt index the registration of the hand is effected. The two hands having been placed exactly parallel, by turning this nut, and bringing the gilt index immediately over the hand, should the latter have subsequently deviated either to the right or the left, the difference will be the result of increased or diminished atmospheric pressure.

MEASUREMENT OF HEIGHTS.

"A less common, but very easy and interesting use of barometrical instruments, is to ascertain the variety of altitudes from the surface of the sea: to which purpose the aneroid is, from its portability, exclusively adapted. By the application of this elegant little instrument, an opportunity is afforded the traveller of learning the level of the railway along which he is passing, even at the utmost speed of the engine. It must be allowed, at least that no *mercurial* barometer, can accomplish *this* purpose. The tourist may by the same means observe the delicate movement of the hand of the aneroid approaching from the word 'fair' to 'change,' as he ascends. So much will this instrument increase the agreeableness of travelling, and supply its possessor with subjects of entertainment and materials for his journal, that it may fairly be anticipated as likely to become the almost indispensable companion of every one who travels either for knowledge or recreation.

Fig. 6.



"An amusing experiment for showing the delicate sensibility of the aneroid, and its power of measuring small heights, may be tried in an ordinary dwelling-house. Any one, on ascending from the basement to the attic, will perceive the gradual approach of the index from 'fair' to 'change,' &c., as noticed above; and its return to its original position, whenever he descends from the attic to the basement. The tenth of an inch is subdivided on the face of the aneroid into four parts; and generally speaking, if the hand goes back one-tenth of an inch, we may fairly conclude that we have ascended from our starting-point about 85 feet; and, of course, *vice versâ*. Calculations may be made according to this proportion."

In the months of May and June, 1849, Major (now Colonel) Robinson, R.E., undertook the task of verifying the use of the aneroid at Portsmouth, and the height of Portsdown Hill was accurately measured by a good spirit-level, and some experiments tried, which at first were not favourable to the aneroid; but on investigating the construction of the instruments, it was found that each should have its own register for indicating heights, from certain peculiarities in their mechanism.

Major Robinson, therefore, taking one sold by Messrs. Manuel, of Portsmouth, (No. 2775,) to the dome of St. Thomas's church, measuring exactly 100 feet, found that ·10 of an inch gave 95 feet, which was verified by going to the summit of a tower at the Point, measuring 75 feet in height.

In measuring Portsdown Hill with the same instrument, he found that 95 feet for every tenth of an inch gave the height 337·6, within two feet, as measured by the spirit-level.

It would seem, therefore, to be necessary, previous to measuring heights, to ascertain practically what the height of 100 feet will be registered by the hands of the aneroid; and as this check may be made as frequently as doubts arise by apparent discrepancies in comparing one aneroid with another, or comparing them with the mercurial barometer, it is conceived that this instrument may be found desirable from

its portability, and the simple mode of finding any height, provided the altitude does not exceed 2000 feet.

The means of reading the divisions more accurately, in the aneroid, must be obtained before *very accurate* and small differences of height can be measured by them: perhaps, if some tracing-paper, with the divisions marked to correspond with the dial-plate, were fixed on the glass by a little gum, the position of the hand would be accurately ascertained; for at present, the eye being placed to the right or left, will cause a variation in the reading.

Major Robinson found that temperature had an effect upon the aneroid he used, amounting to 0·01 of an inch for every five degrees.

G. G. L.

MULE FOR BURDEN.*—The mule is the best beast of burden in a campaign. He is, perhaps, naturally obstinate and intractable, but he possesses many valuable qualities to compensate for these defects. He is strong, temperate, bears great heat, sure-footed, easily fed and got into good condition, but very delicate about the water he drinks. He does not stand fire so well as the horse, and is consequently not so well adapted for draught in Field Artillery; but for Mountain Artillery he is admirably suited.

The mule is seldom sick, but when so, it is frequently fatal; he usually commences work at three years old, though four is a better age, and he continues able to work till about twenty-five.

The produce of the male ass and the mare is preferred to that of the horse and the ass, being much larger and more powerful, but not, for his size, stronger. They may be easily distinguished by their resemblance to their sires: the former also brays, and the latter neighs.

The mule, in Military Service, carries a cargo of from 200 to 300 lbs., with which he can conveniently travel eight leagues (of three miles each) a day, at three to four miles per hour, which is as fast as any infantry can travel.

With light loads he can keep up with cavalry at a trot, from four to six miles per hour.

Mules may be divided into three classes:

	Can carry
1st class. From eight to twelve years old, a little more or less	300 lbs.
2nd class. Twelve years and upwards, and from five to eight years old .	250 ,,
3rd class. Young mules under five years old, and very old mules . . .	200 ,,

In a campaign subject to forced marches, indifferent food, and bivouacking, from 200 to 225 lbs. are considered a sufficient load; because the muleteer, when out of sight, is very apt to ride on the mule.

In Spain, the mules are used for draught instead of horses, even in carriages: the female is preferred for this purpose, as being more tractable than the male, though not so strong.

Those bred in La Mancha, and those bought at the fairs of Padua in Galicia, and Zamora, and fed in the pastures of La Mancha, are preferred for this purpose.

The mule varies from thirteen to sixteen hands high, and sometimes even exceeds this height. The ordinary price is from £10 to £30, and even £60 is frequently given

* By the late Colonel Alderson, R.E.

when broken in for the carriage. It is the custom to clip the mule for cargo over the back, breast, and thighs : that is, over each part touched by the pack-saddle, the breast-plate, and breeching, to prevent sore backs and galling.

The pack-saddle weighs about 60 lbs. : there are various modes of loading.

1st. A pair of panniers of grass, of a triangular or sugar-loaf form, with the peak downwards, thrown over the pack-saddle, the two points being connected by a rope under the belly.

2ndly. By two bales, portmanteaus, canteens or ammunition boxes, containing 1000 rounds of ball-cartridge each, or other heavy substances of nearly equal weights, so as to balance each other. These are suspended on each side of the ridge of the back, as high as possible, by means of ropes passed round them. Such other light articles as are required to make up the load are placed on the back, between the two heavy articles preserving the balance.

A woollen cover, or tarpaulin, is then placed over all, and corded tight.

When the mule is strong, or the load light, the muleteer jumps upon the pommel of the leading mule, having one, two, or more fastened by their halters to the pack of the mule in front of them.

3rdly. By small panniers, or baskets of wicker-work, two or three on each side, connected together, and suspended by loops and toggles. This is the general mode of loading a sumpter-mule ; and if lightly loaded, he will carry your cook, who will be ready to select your billet and prepare your food.

4thly. By two large rectangular panniers, like a writing-case, or lady's reticule, and made of stiff portmanteau leather, with or without partitions in them. They are loaded in a moment, like those of the sumpter-mule, with loops and toggles, by two persons, one on each side, lifting them at the same time : the mule is then ready to march.

In countries where you cannot be certain of obtaining a regular muleteer, as in Spain, &c., this last *is by far* the simplest and best plan ; the panniers, however, should not be made too large, or they will carry their weight too low, which is their only fault, and become inconvenient in crossing fords.

The mules of Syria are much less than those of Spain, and incapable of carrying the same weight : there, however, nature has provided the camel.

R. A.

MUSKETS AND MUSKETRY.*—In this article a short description will first be given of the different small arms in use in the British Service, under the general designation of musket or firelock, and then of the arrangements adopted at the School of Instruction at Hythe, for enabling the soldier to acquire a knowledge of the weapon now employed. These arms are either manufactured at the government establishment at Enfield, under the direction of Col. W. M. Dixon, R.A., Superintendent of Small Arm Factories ; or are supplied by contract, and delivered at the Tower, where they are tested properly, and, if found defective or unlike the pattern, rejected.

The following table gives the weight, length, range, &c. of the arms considered actually according to Regulation ; but it must be borne in mind that the weights assigned are only approximate, as a difference in the locality from which the wood for the stocks is procured, will sometimes cause a variation of fully half a pound weight.

* By Captain Binney, R E.

SMALL ARMS OF THE PRESENT REGULATION PATTERNS.

Description.	Weight.		Length.		Diameter of Bore.	Bullet.			Charge.	Effective Range, about	Remarks.
	Without Bayonet.	With Sword or Bayonet.	Barrel.	Rifle and Bayonet.		Diameter.	Length.	Weight.			
	lbs.	lbs.	Inches.	Inches.	Inches.	Inches.	Inches.	Grains.	Drams.	Yards.	
Enfield rifle (1853)	8½	9¼	39	72½	·577	0·55	1·095	524	2½	1000	Sighted to 900 yds.
Artillery carbine	6½	8¼	24	63	·577	0·55	1·095	524	2½	1000	,, 300 only
Lancaster ditto (oval bore)	7¾	9⅛	31½	72	·577	0·55	1·095	524	2½	1100	
Short rifle, for Sergeants	8	9¾	33	71¼	·577	0·55	1·095	524	2½	1000	
Pistol (rifled)	3	...	10	...	·577	0·568	·863	390	1		
Pistol carbine, for Yeomry	5	...	10	...	·577	0·568	·863	390	1		
			With Butt 2ft. 2 in.								
Naval rifle	8½	...	33	...	·577	0·55	1·095	524	2½		
Sharp's (breach loading)	7¼	...	21¼	...	·577	0·568	0·99	530	2½		Used by Cavalry in India.
The following are obsolete, or nearly so.											
Flint musket	...	12⅕	42	72½	·750	...	...	...	...	180	
Percussion ditto (1842)	10⅛	11⅕	39	72½	·753	·745	...	490	4½	200	
Ditto, rifled and issued to Marines	10⅛	11⅕	39	72½	·753	·745	...	848	3		
Ditto, sea service	9¼	10⅜	30	63½	·753	·745	...	490	4½		
Ditto, rifled and re-issued	9¼	10⅜	30	63½	·753	·745	..	848	3		
Minié (1851)	9 9/16	10 9/16	39	72½	·702	·690	...	696	2½		

It is hardly necessary now to go into an elaborate argument to prove that—so long as war is a calamity which we are unable to prevent—it is not only the part of wisdom, but also of humanity, to make the weapons employed as perfect as possible, of their several kinds; for experience and history alike fully show, that the slaughter has always been greatest where the combat has most partaken of a hand to hand character. Nor need we go out of the way to meet the objection which has been raised by the advocates of "Brown Bess," that it was sufficiently good for its purpose, and that, if the ordinary rank and file were armed with weapons of a higher description, they would be sure to make some mistake in use, and that thus the very perfection would tend to evil; for it has been clearly shown that most British soldiers, when properly trained, are quite capable of using the improved weapon with great satisfaction to themselves and advantage to the service. This *training*, however, is *absolutely necessary*, and too great attention cannot be given to perfecting and extending the system of instruction now carried on at Hythe, and thence gradually exerting an influence over the whole army.

It will now be assumed as granted, that it is expedient to have the most perfect firearm possible, *i.e.*, one combining strength, lightness, durability, and ease and rapidity of loading, with accuracy of fire, and freedom from fouling after any amount of firing; and further, that, having such a weapon, it is also necessary to render the soldier as much as possible master of it, so as to use it to the best advantage. Before, however, proceeding to this part of the subject, a few remarks will be made on the firelocks in use at various periods.

After the introduction of gunpowder, the long and cross-bows gradually went out of use, being superseded by the matchlock, which was employed many years, till the separate match was discontinued, and the flint-lock, set in motion by a trigger, was substituted. This arrangement continued, with slight occasional improvements in the actual workmanship—but still liable to the very serious fault of frequently missing fire—until 1842; at which time a great advance was made by substituting, for the flint and steel, the percussion cap and hammer, by which, although greatly objected to by some who thought every novelty an error, a considerable improvement was effected in the certainty of the musket. Yet still the most serious evil continued, viz., that, in consequence of the great windage necessarily given to smooth bore muskets, to allow for fouling, the bullet did not leave the muzzle of the firelock with its centre coincident with that of the bore; but, after being driven against the lower side of the barrel by the force of the explosion passing over it, and then rebounding against the top and bottom alternately, at length quitted the piece in a direction opposite to the point on which it last impinged.

The irregularity of flight was also greatly increased by the old method of casting bullets, which were generally found to be uneven on the surface, and to enclose an eccentric cavity caused by the unequal cooling of the lead. This style of casting was almost entirely given up in 1842, and the mode adopted of making long leaden ingots or rods, afterwards compressing them between successive sets of rollers which gradually formed the spheres, and then cutting the spheres free by a hand-machine. This mode of construction made the bullets much more solid and comparatively homogeneous.

Many attempts had been made during these periods to arrange some means by which the windage might be diminished, and the range and accuracy of the bullet increased; but little benefit had resulted. Until Robins's time it had been supposed that the tightness of the bullet and consequent friction against the sides of the barrel, produced improved range and direction; but he shewed that the friction was a disadvantage, and that the real advantage was that the force of the gas was retained behind the bullet, till it moved forward, instead of escaping at its sides. One of the

first attempts was that of making the bore of the musket hexagonal, and casting a bullet having the diameter of the inscribed circle; which bullets therefore filled up the whole space except the small grooves or angles of the hexagon, where the foulness was deposited without clogging the barrel.

Further investigation led to the conclusion that to ensure greater accuracy it was necessary to make the grooves in a spiral form, and to raise ridges or belts on the surface of the bullet which should fit the grooves, and cause the bullet itself to rotate on an axis nearly coincident with that of the bore; by which means the inequalities of surface or mass would be constantly turned on different sides, and thus equalise the flight in a considerable degree. This arrangement had to a certain extent the desired effect; but the great force required to overcome the friction caused by the belts, in ramming down the bullet, rendered the weapon unsuitable for the line, and caused it to be confined to a comparatively small number of riflemen or marksmen, trained to act in some degree independently.

In 1851, the first great step in advance was taken by the introduction of the Minié rifle or musket, with which a few companies were armed, and the principle of which has been since then further carried out.

The great advantage of the class of weapons known by this general designation is, that, while the loading is performed with quite as much ease as in the smooth-bore musket, the bullet, when fired, fits into the grooves and acquires the same rotatory motion that was gained by the old rifle and its belted ball. This is caused by the force of the explosion in rear, and the resistance of the air in front, compressing the bullet in the direction of the line of fire, and consequently enlarging it in a lateral direction; by which it is made to fill the grooves, and thus altogether remove the effects of windage. The bullet for this rifle is cylindro-conical, and has a deep cavity in rear, filled, in the case of the actual Minié, with an iron cup introduced into the cavity, on the supposition that it was required to ensure the expansion of the lead. Subsequent experiments induced the conclusion that the Minié was needlessly heavy and the cup unnecessary and expensive; consequently the Enfield Rifle was adopted, with a smaller bore, a bullet longer in proportion to its diameter, and without a cup.

Since then, some dissatisfaction has arisen in the use of this bullet, and it has been also formed with a cavity, but of a different form from that of the Minié, and filled with a small wooden plug in the form of a conic frustum; but great doubts are expressed by many good judges as to the propriety of restoring the cup.

One important advantage of the solid conical bullet, over the hollow one with a cup, is that the former can be easily cast, if necessary, on service, while the construction of the cavity, and cutting or turning the little cup of wood or iron, require skilled workmen and proper tools.

The Enfield is the weapon treated of in the following pages, not on account of its superiority to others, but because it is that at present chiefly used in the Service by the Infantry of the Line. Superior accuracy and rapidity of fire have been claimed for the Whitworth, the Bouchier, and the Lancaster Rifles, all of which have bullets without cups or plugs. The last is used by the corps of Royal Engineers, and has been, on many occasions, tried in the roughest practice and under very unfavourable circumstances. It is stated to have almost invariably shown a higher result than the Enfield, except when, during one set of trials, the bullets stripped in consequence, as it is believed, of the grease employed being mixed with wax.

The main points now in question, with reference to the rifle, seem to be whether the grooves shall be broad and shallow or narrow and deep; and as to the bullet, whether it shall be formed with or without a cavity in the rear, and with or without a plug. On these points a comparison of the different experiments, and the arguments adduced

on both sides, appear to show that, although the weapons with deep narrow grooves and plugged bullets have given a very good result, when used carefully and not too long; yet, to support continued rough usage and rapid firing, the broad, shallow furrows without angles, and the solid bullets are to be preferred; the latter having also, as before said, the additional advantage that they can, if necessary, on service, be cast in the ordinary manner. Further careful comparison is however required before deciding.

In order to remove fouling, which is the evil most to be dreaded, the following method has been successfully practised. As soon as the barrel is found to be a little foul, the rifle is loaded without removing the paper left after pouring the powder into the barrel. If the first round fired in this way does not succeed, the second generally will do so.

The ordinary mode of loading is to bite off the twisted paper covering the powder, pour the powder into the barrel, reverse the ball, and enter it into the barrel to the depth of the cylindrical part, then tear off the paper not required, and ram down lightly; but it appears, by the practice in the Royal Laboratory, that it answers equally well (instead of biting) to hold the cartridge in the right hand and tear off the paper with the forefinger and thumb of the left hand, which is grasping the rifle at the same time.

The following is taken from the course of instruction authorised by His Royal Highness the Commander-in-Chief.

GENERAL COURSE OF INSTRUCTION.

When the recruit has attained a knowledge of the "platoon" exercise, which is to be taught by the adjutant and sergeant-major, his course of musketry drill and practice is to be proceeded with according to the following system.

To this great object too much care and attention cannot be devoted. The rifle is placed in the soldier's hands for the destruction of his enemy; his own safety depends upon his efficient use of it; it cannot, therefore, be too strongly inculcated, that every man who has no defect in his eyes, may be made a good shot; and that no degree of perfection he may have attained in the other parts of his drill, can upon service remedy any want of proficiency in this; in fact all his other instructions in marching and manœuvring can do no more than place him in the best possible situation for using his weapon with effect. A soldier who cannot shoot is useless, and an incumbrance to the battalion.

The Instruction in Musketry is divided into two parts; viz., PRELIMINARY DRILL, and PRACTICE.

Under the head of "*Preliminary Drill*" are comprised the following subjects:—

1. Cleaning arms.
2. Theoretical principles.
3. Aiming drill.
4. Position drill.
5. Snapping caps.
6. Blank firing.
7. Judging distance drill.
8. Manufacture of cartridges.

The "*Practice*" consists of—

1. Firing singly.
2. Firing by files.
3. Firing in volleys.
4. Firing in skirmishing order.
5. Judging distance practice.
6. Firing without using the back-sight.

PRELIMINARY DRILL.

Cleaning Arms.

Every soldier is to be taught the names of the different parts of the lock and rifle,

and the rules for cleaning and keeping them in proper order. Too much pains cannot be taken to impress upon the minds of the men the necessity of preserving their rifles, at all times, in the highest condition, and the impossibility of producing accurate shooting with them when dirty.

Put a little water in the barrel, rub the ramrod up and down in it to remove the dirt, and wipe out with rag or tow until it is perfectly dry, and afterwards with an oiled rag ; then put the muzzle stopper in the barrel, and the snap-cap on the nipple. Care should be taken to keep the snap-cap dry when washing out the barrel, and to wipe the mouth of the hammer before letting it down on the snap-cap. The barrel is always to be wiped clean and dry before use.

The fouling which settles on the stock near the nipple-lump when firing should, if possible, be removed without using water or a damp rag. On no account is a knife or sharp instrument of any description to be used to remove the dirt near the nipple-lump or trigger-plate.

By the foregoing mode of cleaning, the liability of the barrel to become rusty will be very much reduced, and the frequent necessity for removing it from the stock, which is always objectionable, be obviated.

In order to prevent water soaking into the stock, and at the same time to give it a smooth and polished appearance, rub it over well with oil, and apply a little bees-wax between it and the barrel, and between the lock-plate and stock, to prevent water getting under the barrel or into the lock.

In order to ensure a true and easy action of the lock, the several pins, pivots, &c. should be perpendicular to the lock-plate, which is, or should be, a perfect plane.

Pull-off.—It is erroneous to suppose that by loosening the sear or any other pin, an easier or lighter pull-off is obtained ; such a measure is only calculated to impair the lock, by causing an increased wear and tear of the parts, which are thereby thrown out of truth. When the pull-off is too great, either the full bent and sear-nose are not well adapted to each other, or the sear spring is too strong ; these defects, which cause an alteration of the aim when firing, are easily rectified by the armourer when necessary, but must never be attempted by the soldier.

Wood-bound.—The lock is said to be wood-bound when the parts are embedded in the woodwork of the stock, and are thereby prevented from exercising their proper functions. This defect, while it may arise from the swelling of the wood in damp weather, or if exposed to wet, is often occasioned by screwing the lock too tightly to the stock. The side nails, as also the pins of the lock when screwed home, should not protrude beyond the outer side of the lock-plate. The ends of said nails and pins (except the bridle-pin, which, being flat, should be flush) are rounded off to the lock-plate, and present no edges.

Miss-fires.—The non-explosion of the percussion cap is often attributed to the weakness of the mainspring ; this may sometimes be the case. In the majority of instances, however, the defect may be traced to the dirty or rusty state of the tumbler-axle-hole, and axle of tumbler, which necessarily impedes the fall of the hammer, and consequently reduces the force of the blow that is essential to explode the cap ;—and frequently from the cap not being pressed firmly home on the nipple, which prevents the hammer acting with full effect.

The non-ignition of the charge by the cap, very often arises from an accumulation of dirt at the base of the touch-hole.

These causes of miss-fire point to the necessity of great care being taken in cleaning the rifle, to prevent dirt remaining in the touch-hole, or water entering the lock by the axle hole ; and of attention being paid to the instructions for capping.

Miss-fires may be also occasioned by the communication-hole (that is, the hole by

which the detonating spark is conveyed to the charge), not being of sufficient size—or by the nipple-screw being too long; the consequence of which would be that, when screwed down, it would shut up a part of the communication-hole, and prevent the powder from getting into the chamber; or from the nipple being too large for the cap. These defects should be remedied by the armourer.

The soldier should be careful to see that his nipple is in good order, as the instructor will naturally attribute "miss-fires" to a dirty rifle, which marks the inattentive soldier, and exposes him to punishment.

The barrel.—The soldier cannot be too careful of the barrel of his rifle to prevent its being bent or dented, either of which defects is very serious as regards accurate shooting, and seldom occurs except from carelessness; if he suspects that his barrel is either bent or dented, he should report the circumstance immediately.

The soldier is on no account whatever to use his rifle for carrying any weight, or for any purpose for which it is not intended, as the barrel is bent very easily.

Placing arms forcibly in a rack, or piling them carelessly, in consequence of which they often fall down, will frequently set or crook the barrel, more particularly at the muzzle, where it is the thinnest; and this being the point of delivery, the arm becomes irreparably damaged.

Care should be taken to protect the fore-sight from being bent, blunted, or injured in any way.

If the interior of the barrel be allowed to become rusty, the increased resistance to the passage of the bullet will probably cause the latter to "strip" (or pass out of the grooving), or else the wood plug may be driven through the bullet, and the arm for the time rendered useless. Rust in the barrel will also prevent the proper expansion of the bullet, and impair its rotation, which is essential to produce accurate shooting; it will likewise render the rifle difficult to load. If a soldier cannot prevent this, by keeping his barrel clean, he is not fit to be entrusted with a rifle. Rust is caused by the joint effects of moisture and air; the surest way, therefore, of preventing rust in the barrel is to keep the bore perfectly dry, and invariably to have the muzzle stopper in it, and the snap-cap on the nipple, so as to exclude all air.

The soldier should be enjoined to be careful, when skirmishing, not to run the muzzle of the barrel into the ground; should he accidentally do so, he should ask permission to fall out to remove the dirt, for, if the rifle be fired, the obstruction in the muzzle is liable to burst the barrel: if not loaded, the dirt should be carefully removed and the barrel wiped out, for if rammed down with a charge, it would tear the barrel and destroy the surface of the bore.

Ammunition.—The greatest attention must be paid to the cleanliness of the inside of the pouches, so that no dirt or dust may adhere to the greased part of the cartridge.

Whenever there are any loose cartridges in the pouch, they should be folded in paper, in order that they may not shake about and become damaged. To preserve the ammunition in an efficient condition, the pouch should always be well packed, and no vacant space allowed to remain in it.

As powder when damp will not send a bullet so far as when perfectly dry, and as it is also more difficult to ignite by the detonating spark from the percussion cap, the cartridges and percussion caps are always to be kept as dry as possible.

When on picquet, or whenever the rifle is likely to be exposed to rain when loaded (which should never be allowed, if it can be avoided), the soldier should remove the percussion cap and place the snap-cap on the nipple instead. In the absence of the snap-cap, stop up the nipple with grease, easing the spring in either case; if there be no grease at hand, drive a peg of soft wood into the nipple and put the cap on.

Neither the grease nor the peg will in any way impede the action of the percussion cap if properly pressed home on the nipple, as both will disappear on the explosion.

No non-commissioned officer or private is on any account whatever to be allowed to remove his lock from the stock, and take it to pieces, until he is thoroughly acquainted with the foregoing instructions in detail, and has been officially certified by the officer-instructor to be capable of doing so accurately and efficiently. As the barrel seldom needs removing from the stock, this service, which requires great care in its execution to prevent the head of the rifle from being broken, is invariably to be performed by the regimental armourer or his assistant, more particularly as the ordinary turn-screw is not adapted either to remove the breech pin, or to screw it home again.

Theoretical Principles.

This branch of the instruction is specially confided to the officer-instructor, who is to explain the principles thereof in the following order, in a clear and concise manner, and in language suited to the capacity of the men, as it is most important that they should well understand the reasons for all those rules which have to be attended to in practice.

A black board and a piece of chalk are made use of to describe the figures.

The instructor is first to explain the construction of the barrel, as far as is necessary, to show that the upper surface does not lie in the same direction as the inside or bore, with a view hereafter to show that the barrel thus constituted gives elevation in itself.

That the "axis of the piece" is an imaginary line along the centre of the barrel, which denotes the course taken by the centre of the bullet whilst under the influence of the exploded powder, and the distance and direction in which it is guided in its flight. A B, fig. 1, plate 1.

That the "line of fire" is the direction in which the bullet would fly, and with uniform velocity, were it not impeded by the resistance of the atmosphere, and drawn from it by the force of gravity. B C, fig. 1.

The instructor will now proceed to explain that the atmosphere is an elastic fluid, consisting of a multitude of small particles which cannot be moved or set aside by the bullet, without imparting to it some degree of reactionary force, and thereby reducing at every moment the velocity of its flight; and that the greater the velocity with which the bullet is proceeding, the greater is the resistance it meets.

That the "force of gravity,"—a power which draws all unsupported bodies to the earth,—commencing to act upon the bullet as soon as it quits the muzzle, draws it towards the ground with greater velocity in proportion to the time it is exposed to its influence.

That these two distinct motions,—the one increasing as the other diminishes,—cause the bullet to move in a curved line called the "trajectory;" that for a short distance, in consequence of the great velocity of the bullet in its forward motion, and the comparatively short time that gravity has had to act, the course of the bullet scarcely deviates from the line of fire; and that the curve increases more and more in proportion as the bullet becomes more distant from the muzzle. B D, fig. 1.

The instructor will next proceed to show how a knowledge of the laws referred to above can be applied in practice. He will first cause the men to observe that if the "axis of the piece" is directed upon an object, the bullet will never hit it, but for the reasons before explained, will always pass below it. As therefore it has been found by experiment that in the first 100 yards the bullet falls about 1 foot 5 inches, it will be necessary that the line of fire should be directed to a point 1 foot

5 inches above the mark it is desired to hit at that distance; in which case the "trajectory," conforming to the movement of the line of fire, will also be raised 1 foot 5 inches, and the bullet will strike the mark.

In the second place, it is explained that, to fire with accuracy, it is necessary the sights should be carefully aligned between the eye and the mark; that if, however, the sights on the upper surface of the barrel were so constructed as to be in the same direction, or in other words, parallel to the axis, or if the barrel were as thick at the muzzle as at the breech, it would then be necessary, at 100 yards, to aim 1 foot 5 inches above the mark; but that by doing so, the firer would lose sight of said mark, and consequently be uncertain of his correct elevation. That, to obviate this difficulty and drawback to accurate shooting, the height of the lowest back-sight of the rifle is so arranged, that (together with the difference in thickness of metal of barrel between the breech and muzzle) when aim is taken straight at an object 100 yards distant, the "axis of the piece" receives the necessary degree of elevation. C G H, fig. 1.

He proceeds to shew that if the 100 yards' sight were used to fire at a mark 200 yards off (aim being taken straight on the object), the bullet would pass below it,—with a view to prove that the 100 yards' sight does not give a sufficient elevation for the increased distance. It is explained that as at the distance of 100 yards, so at all other greater distances, the "line of fire" must be directed as much above the object as the bullet passes below the said line *when laid horizontally* at those distances; and that in order to enable the firer to aim straight at the mark at all distances, the back-sight is made capable of adjustment by means of a flap and sliding-bar, and thus becomes available for all ranges from 100 to 900 yards; so that if the firer is certain of his distance, and adjusts his sight accordingly, he need not trouble himself about the elevation, which is arranged for him in the construction of the sights. He shews further that, for distances beyond 900 yards, the firer must determine the elevation by raising his eye as much above the back-sight as he may think necessary, always keeping the fore-sight in line with the object; and if under 100 yards (M, fig. 1), that allowance must be made for the slight rise of the "trajectory" above the "line of sight," by aiming a few inches under the mark; viz., about 8 inches will be sufficient at 50 yards, and about 4 inches at 30 yards.

A simple method of practically illustrating the principles which regulate the adjustment and position of the sights is by means of a model gun, having a small spring in the barrel to project a dart, or pointed wooden bullet, with sufficient force to penetrate a target at a short distance, and a folding back-sight with sliding bar on the barrel, to afford three "lines of sight;" viz., one on the surface of the barrel parallel to the axis, one for the distance of about four feet, and one for about eight feet. Put a stopper in the muzzle, with a string tied to the centre to represent the "line of fire," and have another string to show the "line of sight"; first place the gun at the distance of about four feet from the target, and direct the "line of fire" upon a bull's-eye marked on the target, on the same level as the axis of the gun or muzzle; this being done, remove the muzzle-stopper and fire the gun, when it will be seen that the bullet or dart will strike the target below the mark; then measure the fall of the bullet, and place a spot upon the target as much above the bull's-eye to be struck as the bullet has fallen below it, and direct the "line of fire" upon said spot; again fire the gun, when the bull's-eye will be struck. Here make the soldier look along the sight which is parallel to the axis, and he will observe that the muzzle hides the bull's-eye from view; thus, he will see that by directing the "line of fire" on a spot as much above the object to be hit as the bullet falls below it, he has no security that the sight is properly directed, nor has he any guide to the elevation, except the previous measurement, which would of course be impracticable when firing with a

musket. After this, raise the folding sight and the eye, without altering the position of the gun, until the fore-sight is in a line with the bull's-eye ; then raise the sliding bar to the height of the eye, and make a mark on the flap to show the elevation due to the distance of four feet, so that when it is again intended to fire at this distance, the firer has only to raise the sliding bar to the mark on the flap, and aim straight at the object. Let the gun now be removed to a distance of about eight feet, and make use of the same sight that has been previously adjusted for four feet, when it will be seen that the bullet or dart will strike low, thereby showing the necessity of using a higher back-sight for this distance, and the importance of knowing correctly the distance from the mark, in order to regulate the sight accordingly. The stand on which the gun is fixed (Fig. 10, plate 2) should have a hinge at A, to enable the instructor to demonstrate the effect of inclining the sights to one side; to be treated of in the following paragraphs.

In order to explain the foregoing sections on the "line of sight" more thoroughly, the instructor will cause the breech-pin to be taken out of a barrel, and a plug of wood, with a hole bored in the centre, substituted in its place, and put on the muzzle a cap or ring fitted with cross wires ; he will then place a barrel on a traversing rest, and cause the men to aim with the 900 yards' sight at a spot on the wall or black-board, and afterwards to look through the barrel, with a view to observe the angle formed by the "line of fire" and "line of sight."

Whilst the barrel is still upon the traversing rest, the instructor will explain to the men the importance of holding the sights upright ; that the bullet, instead of hitting the mark aimed at, will invariably strike on that side to which the sight is inclined, and that the greater the distance the greater will be the error due to any inattention in this particular. To make this subject clear, let a vertical line be drawn on the black-board, and a spot made thereon to aim at, and cause the men to aim at said spot with the 900 yards' sight, which must be perfectly upright, and afterwards to look through the barrel, directing their attention to the fact of the cross wires cutting the vertical line above the mark aimed at ; then cause them to aim at the same spot with the same sight, *but inclined to one side*, and to look through the barrel again, when they will see that the "line of fire," instead of being directed upon the same vertical line as before, is directed to that side to which the sight is inclined : and, as the "trajectory" always conforms to the "line of fire," the bullet, instead of hitting the mark, would strike on that side. Fig. 3, plate 1.

Further explain that not only is the direction affected by the inclination of the sight, but the elevation also, which is thereby lessened. This will be made very clear by placing a card, with lines drawn upon it (fig. 4), to represent the proper height of the back-sight, at each distance, vertically at the back of the sight, when the men will observe what amount of elevation is lost by any degree of inclination of the back-sight.

Both the error of direction and elevation caused by the inclination of back-sight may also be shewn by a small model gun (fig. 5) with wires affixed to it to represent the "line of fire," the "line of sight," and "trajectory ;" the "trajectory" is made to hinge upon the "line of fire" to show the exact course the bullet will pursue at any degree of inclination of back-sight ; as also that the "trajectory" always preserves the same relative position below the "line of fire."

He explains the height of the "trajectory" at the several ranges, and the distance at which cavalry and infantry are under the power of the rifle when fired with the several elevations marked on the back-sight, in order to impress upon the men the great importance of training themselves to judge distance. It has already been shown how necessary it is that the back-sight of the rifle should be adjusted to the correct

distance; but the soldier cannot do this if he is not thoroughly trained to judge distance by the eye. It is of no use his being a good shot at a fixed mark if he cannot hit the enemy in the field; this is the object of all his training.

It has been ascertained by experiment that if the rifled musket, pattern 1853, be fired with the elevation due to 600 yards at an object 570 yards off, the bullet will strike 2·38 feet above the mark; if the rifle be fired with the same elevation at the distance of 630 yards, the bullet will strike 2·54 feet below the mark, showing that any error of 30 yards in the appreciation of distance would, at this range, cause the soldier to strike the figure of a man either in the head or feet, according as the error of appreciation was under or over the correct distance. When firing with the 300 yards' sight, the bullet will, in passing over a distance of about 70 yards, fall half the height of a man, owing to the "trajectory" of 300 yards being less incurvated than that of 600 yards. At 800 and 900 yards, the curve being greater than at either of the above-mentioned distances, the same fall would take place in passing over a much shorter distance; consequently the greater the distance the greater the necessity of knowing it accurately. It is for this reason that none but well-trained soldiers should ever be allowed to fire at such distances as 800, 900, and 1000 yards, at smaller objects than columns of troops, whose depth would make up, in some degree, for the malappreciation of distance. Thus, in firing at a column of which the depth is 100 yards, if the soldier over-estimates the distance of the front rank by 100 yards, (although such an error would cause him to miss the front rank), he would, if the ground were level, strike the column in its rear. As the soldier, however well trained, cannot always be certain of his distance, it is preferable when in the field, to give the first shot an elevation rather under than over the correct one; the shot will then strike the ground before reaching the object, and may possibly hit in its bound, or ricochêt, as it is called. He should be taught to watch the effect of his shot, which may generally be acertained by observing the dust thrown up when the bullet strikes the ground; he can then adjust his sliding bar according as his first shot strikes before or beyond the object.

The instructor will now proceed to explain the effect of the wind, sun, &c. when firing.

Wind, being air in motion, when blowing from the right will carry the bullet towards the left of the mark, and *vice versâ*; when from the front it will slightly reduce the speed of the bullet, and when from the rear increase it—causing in the former instance a reduction, and in the latter an increase, in the range in proportion to its force and the distance of the object fired at. The soldier is to be informed that a wind from the front or rear does not produce so much effect as a side wind; and that he must be guided entirely by experience in making an allowance for wind, as no fixed rules can be laid down for his guidance, further than that if the wind, for instance, is blowing from the left he must aim a little to the left of the mark; if he finds that the bullet still strikes to the right, he must make a little more allowance in firing the next shot.

When the sun is shining from the left it lightens up the left side of the fore-sight and the right side of the notch of the back-sight; the firer, in taking aim, is apt to be guided by those brilliant spots instead of the real centres of the notches, and the result is that the axis is directed to the right; when, on the other hand, the sun is on the right, he will be liable to aim too much to the left.

It may sometimes occur that the rifle is not accurately sighted as to elevation, and consequently may carry a little high or low. As the marks on the flap, denoting the height to which the sliding bar should be raised for different distances, are not always exactly in the right place (the sights being all made in the manufactory to one

pattern), the soldier should be cautioned to pay attention to each shot, having only a few to fire at a distance; if it goes low, he must raise his sliding bar a little; if high, the reverse. The sights are not always in the proper line. If the back-sight is to the right the rifle will carry to the right; if the fore-sight is to the right, it will carry to the left, and *vice versâ;* this defect should be remedied by aiming in the contrary direction.

If an object fired at be moving, whether it be a man walking or a horse at a gallop, it is obvious that it will pass over a certain distance between the moment of discharge, and the time that the bullet reaches it; if the body is moving across from left to right, or from right to left, the soldier must aim a little to the front of it; but how much, must depend, first, on the pace it is going, and secondly, on the distance of the object from the firer and the consequent time the bullet will have to travel. The firer must exercise his own judgment in this matter, as no fixed rule can be laid down for his guidance.

If, in loading, the soldier observes that there is not sufficient powder in the cartridge, or should he accidentally spill a portion of it, he must, in firing, aim a little high, otherwise the bullet will fall short of the mark.

The necessity of always loading standing, when practicable, and of keeping the barrel perfectly upright, should also be inculated; for when the barrel is inclined, as in loading on the knee, a great portion of the powder sticks in the fouling on the sides of the barrel, and may cause difficulty in loading.

Whenever the lubricating material round the bullet appears to be melted away, or otherwise removed from the cartridge, the soldier is to be instructed that the sides of the bullet should be wetted in the mouth before putting it into the barrel, as the saliva will serve the purpose of grease for the time being.

The rifle may not have a proper bore; if the soldier finds that his cartridge invariably rams down hard, or is very loose in the barrel, he should not fail to report the circumstance immediately.

In this place the instructor will explain the advantages of a rifled barrel, by pointing out the causes of uncertain fire in the smooth-bore musket, and the means by which they have been obviated.

The chief cause of error in the smooth-bore musket was the excess of windage, which is the difference of size between the bore and the bullet (fig. 6, plate 2). A great amount of windage was necessary with the old musket, otherwise, when the barrel became foul after firing, the bullet would not enter. When the musket is held up to the "present," the ball will rest on the lower surface of the barrel, consequently the whole of the windage will be above. During the explosion of the powder a portion of the gas will escape by the windage, and force the ball down on the lower surface of the barrel at the same time that it forces it out of it. The ball, bounding from the lower surface of the barrel, will strike against the top, and so continue to rebound from the upper surface to the lower, or from side to side, in a zigzag direction, instead of passing evenly along the barrel, the result of which is that on whatever side the ball last strikes the barrel it will receive a reactionary force tending to send it in an opposite direction, and so divert it from the course it is intended to pursue.

The bullet now used with the rifle musket, besides being elongated, and therefore better shaped for passing through the air, is so contrived that in its passage out of the barrel all windage is done away with. This bullet enters the barrel easily, but on the explosion of the powder taking place, the pressure of the air in front, and the force of the explosion behind, have the effect of dilating or enlarging its cylindrical portion so as to make it fit the barrel tightly, precisely in the same way that compressing an orange or an india rubber ball at its opposite ends would widen its other diameter, and

so enlarge its lateral circumference. Thus windage is completely done away with, and the whole force of the explosion acts upon the bullet in the same direction, giving it increased velocity, and obviating those irregularities which have been described as taking place during the passage of the spherical ball through the smooth-bore barrel.

But, besides the irregularities above described, which tend to give the spherical ball a wrong direction, there is also another cause calculated to influence it during its flight: suppose a ball (fig. 8) to be passing through the air in the direction of the arrow A, and that by some accident it had a hollow or unevenness on one side, at B, this will receive the pressure of the atmosphere in the direction of the arrow C, which would tend to divert the ball from its true course and send it in the direction of the arrow D. The elongated bullet would be equally, if not more, affected by any such unevenness of its surface if fired out of a smooth barrel; the error, however, arising from this cause is corrected by the barrel being rifled in the manner described in the next section.

A barrel that has any number of grooves cut down the inside of it, is said to be rifled. These grooves are cut in a spiral direction with a view to cause the bullet to turn or spin on its longer axis. If the men look through the rifle barrel, they will see the grooves and the degree of turn or twist given to them, and give their attention to the fact that, when the grooves make half a turn in the length of the barrel, the groove which is at the one side at the breech turns, and appears on the opposite side at the muzzle, passing over like a female screw from left to right.

When the bullet is expanded by the explosion of the powder, &c. as before described, it is not only made to fit the barrel tightly, but its cylindrical surface is moulded into the grooves in such a way that during its passage through the barrel it is constrained to turn with the grooves, and thus it receives a spinning movement around its longer axis, which continues during the remainder of its flight; this not only prevents a rotation in any other direction, but is in itself a rotation calculated to ensure accuracy of flight, by constantly presenting any imperfection of surface to the air in opposite directions. The object, therefore, of spiral grooves is to correct by the means which have been detailed, the flight of the bullet, and to cause it to spin or rotate in a direction coincident with its flight, thus keeping its point foremost.

The best way of describing the motions of a rifle projectile in its passage through the air is by means of a bent arrow (fig. 9). Suppose the arrow was shot from the point A, with a view to hit the mark C, and no spinning motion was given to it, if the bent point of the arrow were placed upwards, the greater pressure of the air being on its convex side would tend to carry it in the direction D; but if it had previously received a spinning motion, then, by the time it reached E the point would have turned in an opposite direction and have proceeded downwards, descending as far beneath the true "trajectory" in so doing, as it had at first risen above it; thus the arrow would continue throughout its course to move in a spiral direction round the true "trajectory," constantly correcting the error due to its imperfect figure, and ultimately it would strike much nearer the mark than if it had received no spinning motion.

After describing the bad effect that any unevenness on the surface of the bullet would produce, he points out to the men, that nothing is more likely to cause this than hard ramming in loading, which, besides indenting the bullet, injures the powder, and should consequently be avoided as much as possible.

In the foregoing part of the theoretical instruction, the soldier will have formed some idea of the laws which regulate the flight of the bullet in the air, and he will also have been rendered thoroughly conversant with the arrangement of the sights and of the barrel, and complete master of all the rules which have been laid down for his

guidance at the moment of firing. The instructor must now impress upon his mind that the accuracy of shooting is not dependent on these causes alone, but also on the attention that he pays to the preservation of his rifle and ammunition, as inculcated in his instruction in cleaning arms.

Aiming Drill.

In this exercise the recruit is to be instructed how to aim, and to adjust the back-sight of his rifle ; and his progress is to be tested by making him aim at the different distances by means of a rest. If traversing rests are not available, a tripod formed of three stakes tied or looped near the top, or piled arms with bayonets fixed (sheathed) supporting a bag of sand about 4½ feet from the ground, will answer the purpose.

The squads, which should never exceed ten men each, are to be formed in single rank at each rest, every man having his own rifle ; and the instructor is first to explain the principles of aligning the sights of the rifle on an object, confining the attention of the recruit to the following simple rules :—

1st. That the sights should not incline to the right or left.

2nd. That the line of sight should be taken along the centre of the notch of the back-sight and the top of the fore-sight, which should cover the middle of the mark aimed at.

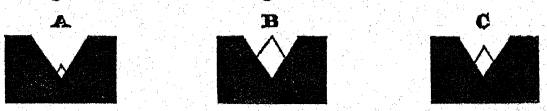
3rd. That the eye should be fixed steadfastly on the mark aimed at, and not on the barrel or fore-sight, which latter will be easily brought into the alignment if the eye is fixed as directed. Particular attention is to be paid to this rule, for beginners are apt to fix the eye on the fore-sight instead of the mark, in which case the latter can never be distinctly seen, and the difficulty of aiming is greatly increased.

4th. That in aiming the left eye should be closed. If a recruit is not able to do this at the outset, he will soon succeed by tying a handkerchief over the left eye.

The instructor will also explain the difference between fine, full, and half-sight in aiming, as follows, viz. :—

1st. *Fine-sight* is when the line of sight is taken along the bottom of the notch of the back-sight, the fine point of the fore-sight being only seen in the alignment ; as A, fig. 1.

Fig. 1. Fig. 2. Fig. 3.



2nd. *Full-sight* is when the point of the fore-sight is taken in alignment with the shoulder of the notch of the back-sight ; as B, fig. 2.

3rd. *Half-sight* is when the point of the fore-sight is aligned midway between the shoulder and bottom of back-sight ; as C, fig. 3.

As the two methods of aiming first named cause a slight difference in the angle of elevation, it is necessary the recruit should understand that the ordinary rules for aiming are intended to apply to the half-sight, and that as some of the rifles may carry high and others low, allowance must be made for such defects, by aiming with fine-sight when the rifle carries high, and with full-sight when it carries low.

After the foregoing rules have been clearly explained, the instructor is to cause each

man to align his rifle with the sight for 100 yards, on a mark that distance from him; having done so, he will leave his rifle on the rest and step aside, in order that the instructor may take his place to see if the aim is correctly laid: and should he discover any error, he is to call another recruit, who is to look along the sights, and to state the defects; on which the instructor will offer some remark as to what the consequence would be if actually firing at an object, and cause the recruit to aim again. This method has the effect of sharpening the attention of the recruit, and of inducing him to avoid, when aiming himself, the errors he may have witnessed in his comrade's aim.

The foregoing proceeding is to be carried out, at every distance of 50 yards, from 100 to 900 yards, (according to the sighting of the rifle) at "bulls'-eyes" of the following dimensions, viz.; from 100 to 300 yards, eight inches in diameter; from 350 to 900 yards, two feet in diameter; in order that the recruit may acquire a knowledge of his sights, and become perfect in aiming; for it must be borne in mind that the difficulty of aligning the fore-sight accurately increases as the distance increases. The instructor is thus enabled to ascertain the progress the recruit is making, and if he has any defect in his eyesight.

This exercise is well calculated to strengthen the vision; and it cannot be too strongly impressed on the mind of the soldier that, to shoot well at long ranges, he must train, and strengthen his eye by looking at small objects at distances beyond those at which he will have to fire in practice.

Position Drill.

In this exercise the recruit, as well as the drilled soldier, is to be put through all the motions of firing, standing and kneeling, with the same accuracy as if actually firing ball, close attention being paid to each movement.

With the view of habituating him to the correct position, and to the natural connection that should exist between the hand and the eye,—the eye being the regulator of every action of the hand,—constant practice is required to enable them so to act together that the hand will readily raise the rifle to any object the eye is fixed upon, and that the forefinger may act upon the trigger at the proper moment.

The "*position drill*" differs from the *platoon exercise;* the latter comprehending the positions of loading and firing in the ranks, in which the soldier is to be instructed by the adjutant and serjeant-major; the former, the essentials of good independent firing, to which the instructor of musketry is exclusively to confine his attention.

This exercise is always to be executed in marching order, and with fixed bayonets,* when standing, and unfixed bayonets when kneeling. The squads, which are not to consist of more than ten men to each instructor, are to be formed in single rank, the men at one pace apart, and placed at any convenient distance from the target or mark.

Before commencing this important drill, of which there cannot be too much if well executed, the instructor is to point out to each man an object to aim at; for this purpose small "bulls'-eyes" are to be marked on the barrack walls, the painting of which is to be done by the troops, who will be furnished, on requisition to the barrack-master, with the necessary tools and prepared black and white paint. The bulls'-eyes are to be white, of the size of a crown piece, and having a black centre of the size of a shilling. They are to be placed *two* feet and *four* feet from the ground, one above the other, and at lateral distances of *three* feet.

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* In corps armed with short rifles, it is only the *recruits* who go through the position drill with fixed swords.

This practice is intended to accustom the recruit to handle his rifle expertly, and by strengthening the left arm, to give him a perfect command of it with his left hand; also to habituate him to raise it to the shoulder horizontally without moving his body. It is therefore to be continued until these points are accomplished. No defect, however trivial, is to be overlooked, and the instructor should explain the errors and their bad effects, when the squad is standing at ease.

The most minute attention is to be given to each man's position when at "the present," more especially to see that the sights are upright,—that the rifle is pressed firmly to the shoulder with the left hand,—and that the trigger is pressed steadily without the slightest motion of the hand or arm until the hammer falls upon the nipple; as also that the eye is fixed upon the mark during and after snapping. The instructor is to scrutinise each man of his squad in succession, all the time it is practising, pointing out and correcting the errors he may discover in any man's position; and he is also occasionally to place himself in front of each man, and cause him to aim at his eye, with a view to ascertain that he obtains the alignment quickly and readily, and that his aim is not lost by pulling the trigger. Whenever the instructor discovers a fault in a man's position when the rifle is at the shoulder, he is to cause him to come to the "present" three or four times in succession, without loading, to correct the defect noticed.

The instructor is to explain to the recruit that the explosion of the powder, at the same time that it sends the bullet out of the barrel, communicates a force backwards, which is called "recoil," and that by pressing the butt firmly into the hollow of the shoulder, he may control the consequent "kick" of the rifle, which will otherwise take place. This is of great importance, as the more confidently a man stands up to his rifle, the less likelihood there is of random shooting, and the better will be the results of platoon firing.

Judging Distance Drill.

In this drill the recruit is to be instructed to take note of the size and appearance of men and objects at different distances.

In firing for instruction, the target is generally placed at known and measured distances, but before an enemy the distance is unknown; it is therefore necessary, in order to apply the rules laid down for shooting, that he should know how to judge quickly, and with tolerable accuracy, the distance which separates him from the object he is firing at, so as to regulate the elevation of the rifle.

In order to teach the recruit, as well as the drilled soldier, to estimate distances by the eye, he is to be instructed in the following manner before he is allowed to engage in the judging distance *practices*.

Men are to be placed as "points for observation" at the distances of 50, 100, 150, 200, 250, and 300 yards, facing the squad or party, standing at ease, looking to their front, and remaining in an erect position, unless ordered to the contrary.

These "fixed points" are to be thrown out in the following manner. The instructor is first to select a tree, house, or any other conspicuous object in the distance, and align two men thereon, twenty yards apart and facing each other, and place ten paces to the right or left, (as he may think proper), of the nearest man and in the same line, another man as a point for covering; after which he is to march a squad of six men, formed two deep, on the alignment chosen, and halt it at 50 yards distance, when No. 3 of the rear rank will face about and cover the two men already aligned; the man 20 yards off will now be removed. The squad is then to make a half face to the right or left, and march in an oblique direction for a distance of $50\frac{5}{8}$ yards, or 61 paces,

when it is again to halt and No. 3 of the front rank is to face about three quarters either to the right or left, and cover diagonally, moving to the right or left by the side step, as may be required, preserving his shoulders square to his present front. The squad is to continue so to march in an oblique direction, leaving a man at every distance of 61 paces or 50⅘ yards, who is to act as before detailed, until every man is placed. When the "points of observation" are aligned diagonally, the covering point is no longer required.

It will be observed that each man in the above formation is placed at a greater distance from the line first marched upon, in proportion as he is distant from the point where the squad commences its instruction, in order that each soldier may serve, in turn, as a distance point for the men of the squad to make observations on.

An officer or non-commissioned officer, as assistant or squad instructor, (if there is a sufficient number), is to be placed opposite the several "points for observation," and the squad or party formed to the left of the squad instructor placed opposite the point 50 yards off.

The instructor should direct the men to notice the position of the sun, the state of the atmosphere, and the background at the time they are making their observations, in order that they may be accustomed to the changes made in the appearance of the several objects under their altered condition.

The squad instructor opposite the 50 yards point is then to proceed to indicate to each man in succession the different parts of the figure, arms, accoutrements, and dress, which can still be distinctly perceived on the soldier before him, as also those parts that can no longer be perceived clearly at 50 yards; after which he will question him on the observations made on what he can see, and enjoin him to try and impress upon his mind the appearance of a man at this distance, and pass him on to the next station.

The squad instructor opposite the 100 yards point is to proceed in the same manner, and cause each man to make observations of the same kind as he did on the man at 50 yards, and desire him to make comparisons between the two men placed at this and the former distance, and then pass him on to the next squad instructor, and so continue until every man has made his observations on all the points.

The squad instructor opposite the point 300 yards off should endeavour, above all, to point out to each man, according to the observations he may make, the differences that exist between the men placed at the six distances comprised in the sub-divisions of 300 yards, as also what parts of the figure, dress, and equipments are distinctly perceptible, those that are seen less clearly, and those that are no longer visible, at each distance.

The instructor must not expect that the answers and observations should be the same from every man, since the eyesight is not the same in all.

The men who are placed as "points" are to be relieved by others who have made their observations at the several distances, for which purpose the squad is to consist of at least double the number of men employed as "points."

Should the party be very large, points may be thrown out right and left; and in order to afford a view of the men at the several distances in two aspects, points may be thrown out in the opposite directions.

When all the men of the squad, or party, have made their observations on the different points, they will proceed to estimate the distances of men within the limits of 300 yards in the following manner:—After having marched the squad on to a different ground from that on which the appreciation of distances has before taken place, the instructor is to place a man at any unknown distance, unobserved if possible, by the squad, formed opposite said man, who is to stand at ease. He is

then to order the men to observe the soldier facing them, and to estimate the distance, cautioning them at the same time to recollect the appearance of the men just seen at known distances.

The squad instructors having formed three paces to the front of the right of their squads are to call each man separately to the front and question him, noting down in a register his answer, which must be given in a low tone of voice, in order that those following him may not be influenced by his opinion. No talking is to be allowed while the answers are being given. Every man will adjust the sight of his rifle for the distance he judged.

When all the men have given their answers, which are to be read over to them by the squad instructor, in order to ascertain if they are correctly recorded, the squad will proceed to pace the distance, by marching towards the man judged from; the instructor placing himself in the centre, and counting the number of paces aloud, the men only counting them to themselves.

The men should be taught to record the distance as follows :—At every 120 paces they will double up one finger of the right hand, to mark 100 yards; commencing again 1, 2, 3, and so on. When at the end of any division of 100 yards the remaining distance appears to be within 100 yards, they will commence to count by *tens of yards*, by doubling up a finger at every 12 paces. The correct distance, which is to be promulgated will, in every instance, however, be ascertained by actual measurement with a cord, chain, or pace-stick, by men following immediately in rear of the squad.

The recruits, after they have been drilled four different days to 300 yards, in the manner before detailed, are to be exercised for four days more up to 600 yards, first at known distances, in every respect as laid down for exercising to 300 yards, the "points for observation" being two or more men, placed at every fifty yards from 350 to 600 yards inclusive, after first measuring 300 yards on the alignment chosen.

When estimating unknown distances beyond 300 yards, the party, with a view to save time and walking, is to be separated into two equal portions, moved in different directions, and when halted, facing each other, with a file thrown out on the flanks a few paces off. After every man has judged the distance which separates the parties, and the answers have been recorded, they are to advance towards each other, counting the paces as before; each party measures half the distance, and the two added together will give the correct distance.

The instructor, in repeating these exercises, is to take care that they are conducted, as much as possible, in different directions, and under different states of the atmosphere, in order that the soldier may become habituated to the diversity of circumstances in which he may have to act.

It is to be observed that every judging distance drill is to consist of making observations on men placed at known distances, and of giving three answers on men placed at unknown distances in different situations immediately afterwards.

PRACTICE.

Target Practice.

Target practice affords proof of the attention bestowed on the preliminary drills; the more carefully the latter have been performed, the better will be the result of the ball firing.

The targets are to be six feet in height and two in breadth, constructed of iron of sufficient thickness to be rifle-bullet proof, having squares of six inches cut on the face to facilitate the marking off of the hits in the diagrams provided for the purpose,

as also circular rings of eight inches and two feet in the centre, to serve as guides in painting the "bull's-eye" and "centre."

The targets are to be coloured *white* with a mixture of whiting, water and size; and the "bull's-eye," and circle describing the "centre," *black* with lamp-black, water, and size. Pots of these mixtures should be kept in rear of the targets.

The targets are to be rested on a stone or wooden platform, twenty feet by nine inches, which is to be laid at right angles to the line of pegs denoting the several distances, and when in use they are to be as perpendicular as possible.

The greatest care is to be taken when lowering or raising the targets, to prevent their being damaged; they are on no account to be allowed to fall by removing the props, but are, in every instance, to be carefully let down on the ground.

When the targets are laid on the ground they should be placed at an incline to prevent the rain lodging on them; and with a view to preserve them from the effects of exposure, they should be painted periodically.

In all cases, where the nature of the ground admits of it, a trench is to be dug for the "markers," of the sufficient dimensions, about fifteen yards to the front and to one side of the targets, and in such a position that the markers may easily see the face of the target from it; the earth excavated should be thrown up on the side of the firing; there should also be two epaulments, so as to screen the men, not only from the shots themselves, but from any stones that may be thrown up by them. The only fitment required for the marker's butt is a seat. About eighty yards in rear of the marker's butt, a smaller butt, capable of holding two men, is to be made on every practice range, for the purpose of signalling ricochets that may hit the target. Should the ground be such as to render it impossible, except at a considerable expense, to erect marker's and ricochet butts, iron mantlets or screens will be supplied on application to the barrack-master.

Every range is to be carefully and accurately measured by an officer of the engineer department, and the distances defined, at intervals of fifty yards, commencing at 100 yards from the target and continuing to 900 yards, or the extremity of the range, if under that distance.

The shots that strike the target are to be denoted by flags of different colours raised above the butt. These flags, together with the number of points fixed as the value of the shots, are as follows:—

	Shots.	Flags.	Value in points.
In the practices at distances beyond 300 yards.	Outer	White or yellow	1
	Centre	Dark blue	2
	Bull's-eye	Red and white	3
	Ricochet	Red flag waved in front of the butt	R
	Miss		0
In the practices to 300 yards inclusive.	Outer	White or yellow	1
	Centre	Dark blue	2
	Ricochet	Red flag waved in front of the butt	R
	Miss		0

The signal for "danger," or "cease firing," is in all cases to be a *red flag*. This will be hoisted whenever it is necessary to cease firing to re-colour the targets, or for any other purpose. No man is on any account to leave the marker's butt until the "cease fire" has been sounded, or the danger flag raised at the firing point in answer

to the danger signal. The red flag is always to be kept up as long as the markers are out of the butt, or any person is in the line of range. Whenever the "cease fire" is sounded from the firing point, it is to be immediately answered from the marker's butt by raising the danger flag; and in like manner the "commence firing" is to be answered by lowering it.

Ricochets, or shots which strike the ground before hitting the target, are to be signalled by waving the red flag twice, two and fro, in front of the target, and are to be counted as misses in individual firing, but noted in the register by the letter R. The men in the ricochet butt are to keep a sharp look out, and to call out to the non-commissioned officer in the marker's butt "*ricochet*" when such is the case.

The instructor is to be cautious not to check a man for any error he may observe at the time he is firing, as it would have the effect of distracting his attention from the object he is aiming at; but is to watch attentively the position of each soldier, and correct him, if necessary, after he has fired.

Every recruit is to expend in his training, and every drilled soldier in his annual course of practice, (except in the cases hereinafter specified), 90 rounds of ball ammunition in the following manner; viz.—

60 in individual firing,
10 by files,
10 in volleys, and
10 in skirmishing order.

The number of rounds to be expended at each distance, the distances and number of targets to be fired at by the several classes in individual firing, and the size of the bull's-eye and centre for each class, are as follows:—

	Yards.	Rounds.		
3d class	150	5	two targets	having a bull's-eye eight inches in diameter, and a black circle two feet in diameter.
	200	5		
	250	5		
	300	5		
2d class	400	5	four targets	having a black centre two feet in diameter.
	500	5		
	550	5		
	600	5		
1st class	650	5	six targets	having a black centre three feet in diameter.
	700	5		
	800	5		
	900	5		

Target practice is invariably to take place in marching order; and all practices up to 300 yards are to be performed standing; beyond that distance, kneeling.

The practice of *individual* firing for *recruits* comprises "preliminary ball practice" and "first" and "second periods;" and for the *drilled soldier*, as his annual course, "first," "second," and "third periods," in each of which twenty rounds are to be fired.

Young officers and recruits are on no account to be permitted to fire ball until they have been exercised in all the subjects embraced under the head of "preliminary drill;" and the drilled soldiers of the battalion are not to be allowed to fire their annual allowance of practice ammunition until they have been first similarly exercised.

Firing Singly.

In this practice the young officer and recruit are to fire five rounds at 100, 150, 200, and 250 yards at two targets, standing, with fixed bayonets; one round at each distance to be fired off a stand or rest.

In the first period of individual firing every man, *recruit or otherwise*, is to practise at every fifty yards from 150 to 300 yards inclusive;—all those men who have obtained fifteen points and upwards passing into the second class, and those who have not obtained this number being formed into a third class.

In the second period of individual firing the party or company is to practise in two classes, viz., second and third.

In the practice of the second class the centre is to be painted black, and the points allowed to reckon for a bull's-eye are to be discontinued.

At the conclusion of the practices in this period, the points obtained by each man at the several distances are to be added together, and the sum entered in the columns "total points," from which a second classification is to be made, when all men of the second class who have obtained twelve points and upwards are to pass into the first class; and all men of the third class who have obtained fifteen points and upwards into the second class.

In the third period of individual firing the party or company is to practise in three classes, viz., first, second, and third.

In the practice of the first class the centre is to be increased to three feet in diameter, and coloured black; all shots hitting it being counted two.

File Firing.

In this practice ten rounds of ball ammunition are to be expended by the recruit, and by the drilled soldiers of every company annually, at three hundred yards, in the order of file firing detailed in the "Infantry Manual."

The mark for this practice, and also for volley firing, is to consist of eight targets placed close together, each having a separate bull's-eye and centre of the dimensions detailed for the third class.

The bullets striking the target in this practice will have the same value in points as in the third class.

The strength of the squad or section firing in this and the following exercise is not on any account to exceed ten files.

Volley Firing.

In this practice ten rounds of ball ammunition are to be expended by the recruit, as also by the drilled soldiers of every company annually, at four hundred yards, both ranks kneeling. The hits are to be counted as in the second class, bull's-eyes being reckoned only as centres; and in this, and the skirmishing practice, care is to be taken that the men of the third class, who have not fired beyond three hundred yards, adjust their sights to the proper elevation.

Skirmishing.

Ten rounds of ball ammunition are to be expended by the recruit, and also by the drilled soldiers of every company annually, in skirmishing order, as per "Infantry Manual," advancing and retiring between four hundred and two hundred yards, each man judging his own distance, and arranging his sight accordingly.

Eight targets, each having its bull's-eye and centre of the dimensions detailed for

the third class, are to be placed with intervals of six paces between them. Every file is to have its own target, and the hits are to be counted as in volley firing; bull's-eyes being only valued as centres.

In firing advancing, the men may fire kneeling,—rising to load,—which may be executed at the halt, running up to the file leaders after returning their ramrods, and capping after giving the word "ready."

A sentry (one of the fatigue party) is to be placed on each flank of the extended targets, about forty or fifty yards off, to prevent any person approaching within said distance.

At the conclusion of the firing of each squad or section in this practice, as well as by files and in volleys, the company instructor, and a non-commissioned officer of another company, are to go up to the targets and mark off the hits in a diagram.

The average points obtained in the "skirmishing practice," added to the averages obtained in the "first period," and in the practices of "file and volley firing" will denote the "*merit*" of the shooting of the squad, company or battalion.

No man, recruit, or otherwise, is to be exercised in the practices by files, volleys or skirmishing, who has not completed a period of individual firing; nor is a man to be allowed to practise in the "third period" until he has been exercised in the "first and second periods" respectively.

Judging Distance Practice.

The following course of judging distance practice is to be gone through by each recruit, and by every drilled soldier of the battalion annually, with a view to test the proficiency of the several companies of the battalion in this important and essential exercise.

In the absence of an instrument, a cord or chain of the length required for the practice, divided into parts of five yards each, with the distance of each division from the end so marked as to be distinguished only on close inspection, is to be stretched in any direction that may be found convenient, care being taken to vary the ground as much as possible for the several practices.

One or more men, when judging to 300 yards only, but beyond that distance a section of not less than eight or ten file, are to be stationed at the end, or any other part of the chain that may be directed, to serve as objects to estimate from.

The commander having marched his party or class to the place that he intends to judge from, is to halt it about ten paces to the right of the chain or cord facing the object or points, and arrange the non-commissioned officers who are to keep the registers three paces in front of the right of the several sections, to prevent the answers, when given, being heard by those in rear. These non-commissioned officers, after recording their own answers, will call each man of their respective sections to the front to give his answer in yards as to the distance that separates him from the "points," which is to be immediately noted down in the register.

When the answers of every man of the section or class have been taken down, they are to be read over to the men, so that any error as regards entry which may be discovered, may at once be corrected. After this has been done, the commander is to state aloud to the men the correct distance, which is to be noted at once at the top of the column, and the number of points obtained by each man registered at the side of his answer, and made known to him.

The "judging distance," like the "target practice," is to be divided into three periods, each consisting of two practices or twelve answers.

The 3d class is to practise as far as 300 yards, the 2d class to 600 yards, and the 1st class as far as 900 yards.

The value of the men's answers, by points, in the several classes, are as follows :—

3rd class : Or when judging distance between 100 and 300 yards . . .	Within 5 yards .	3 points.
	,, 10 ,,	2 ,,
	,, 15 ,,	1 ,,
2nd class : Or when judging distance between 300 and 600 yards . . .	Within 20 yards .	2 points.
	,, 30 ,,	1 ,,
1st class : Or when judging distance between 600 and 900 yards . . .	Within 30 yards .	2 points.
	,, 40 ,,	1 ,,

In addition to the three periods of judging distance practice above mentioned, which are to be executed concurrently with the corresponding periods of target practice, the men are to be taken into the country by companies, under their respective captains, at least once a month after the annual course of musketry instruction has terminated, to be exercised in judging distance, with a view to develope their powers in this essential particular. They will also be exercised in this practice on marching-out days, for which purpose the halts may be prolonged if necessary. The names of the best judges of distance are to be taken down, and delivered to the Adjutant on the return to the barracks, and such of them as may deserve it may be permitted to be absent from afternoon parade, or receive some other trifling indulgence. When those extra practices take place (which are to be recorded in a register) the same is to be notified in the monthly progress return.

Firing without using the back-sight.

After the annual course of target practice has been gone through, the first and second class men (if there is any spare ammunition), should be trained to fire at 300 and 400 yards with the flap of back-sight down, judging for themselves the proper elevation of their rifles.

Prizes for good shooting.

With a view to stimulate individual exertion, and to reward the proficiency of soldiers in the use and management of the rifle-musket, a system of prizes has been adopted, and the following rules for the award thereof are to be strictly observed :—

The regimental prizes for good shooting are to be three ; viz. :

1st Prize.—To the best shot of a battalion consisting of not less than four companies (all of which must have been exercised through the yearly course of musketry drill and practice) a badge of *cross muskets and crown* worked in gold, and entitling the wearer to extra pay at the rate of *two-pence* per day. This prize is not issued to depôt battalions.

2d Prize.—To the best shot of each company, in which forty rank and file at least (not including recruits in a musketry sense) have practised through the yearly course of instruction, a badge of *cross muskets* worked in gold, and carrying with it extra pay, at the rate of *one penny* per day.

3d Prize.—To certain of the first-class shots to be styled "*marksmen*," at the rate of ten per cent. of the number of men exercised through the yearly course, but not to exceed 100 per battalion, a badge of *cross muskets* worked in worsted, with *one penny* per day additional pay to each wearer. The badges referred to under the head of 1st, 2d and 3d prize are to be worn on the *left arm* immediately above the slashed flap of the sleeve.

The "best shot of the battalion," and "the best shot of the company," are to be allowed, in addition to the reward as such, the extra pay as "marksman," when eligible for the position: but no soldier is entitled to a reward for shooting who is not in the first class in the final classification of the judging distance practice. It is to be clearly understood that the maximum reward for the best shot of the battalion is three pence per diem.

In order to ensure, on the one hand, a high rate of efficiency, and, on the other, to guard against the public being called upon to pay for a lower standard of merit than is necessary, as well as to secure the utmost impartiality in the distribution of the rewards, the practice registers and returns are to be the data upon which the proficiency of the men's shooting is to be estimated.

Accordingly, the best shot of the battalion will be that soldier who, in the practice of the first-class firing between 600 and 900 yards, obtains the greatest number of points over seven.

The best shot of the company will be that soldier who, in the practice of the first class of his company, firing between 600 and 900 yards, obtains the greatest number of points over seven.

To qualify a soldier for the position of marksman, and the rewards attaching thereto, he must, in the yearly course of practice, have obtained at least seven points in the first class, firing between 600 and 900 yards,—must have displayed the requisite skill in judging distances, being at least in the first class at the final classification of the judging distance practice—and possess a competent knowlege of the laws affecting the flight of the bullet, and the rules to be attended to in maintaining the efficiency of the rifle under all circumstances and conditions: which is to be ascertained by examination, conducted in the presence of the commanding officer, by an Inspector of Musketry, when his services can be obtained, and if not, by the officer-instructor of the battalion.

If more than 100 men in the battalion (including the best battalion shot, and the best shot of each company, if eligible) come under the conditions specified in the preceding paragraph, then those men who have obtained the greatest number of points are to be first selected for the reward and distinction. Should two or more men have obtained the same number of points (not less than seven) in the first class, and be otherwise eligible for the reward, reference is to be made to their respective performances in the first and second periods of individual shooting, and those selected who have obtained the greatest number of points therein. Should there still be a tie, reference is then to be made to their performances in the judging distance practice, and the preference given to those who are the best judges of distances.

All men who may undergo a course of instruction at the School of Musketry, Hythe, are, if qualified, eligible for the rewards for good shooting in their respective battalions, provided they have not been exercised in the yearly course of practice before joining the said establishment, which is to be duly notified. Practice returns of men instructed at Hythe will be sent to the officers commanding battalions.

If the number of paid marksmen in a battalion be reduced by casualties during the year, the number may be completed from those men eligible for the reward (if there are any), under the conditions described above.

As a further inducement to all ranks to vie with each other in this essential part of the soldier's instruction, and in order that every man may feel that though he may not himself succeed in obtaining a prize, he can assist in obtaining one for his company, a *Supplementary Prize of cross muskets and crown worked in gold, but unaccompanied by any pecuniary allowance*, will be worn on the *right arm* by the serjeants of the

best shooting company of every battalion. When a serjeant who is the holder of this supplementary prize leaves his company, he is to resign it.

Should a serjeant of the best shooting company be either "the best shot of the battalion," the "best shot of his company," or a "marksman," he is to wear the distinguishing badge of that position in addition to the badge sanctioned in the foregoing paragraph.

With a view to ensure strict impartiality, the several companies of a battalion are to be kept as much intact as possible; they are, therefore, to be equalised before the annual course of drill and practice commences, and no transfers be made, except such as are indispensable, until the period for commencing the practice in the following year.

Although *the best shooting company* can be established, and the company badge be issued accordingly, wherever a range of 300 yards can be obtained, no rewards are to be granted to *battalions* unless they have been practised in the three periods of individual firing; and under no circumstances is the limit of *one* best shot per battalion, one for each company, and one hundred "marksmen," *including the two former*, ever to be exceeded. Further, both the badges and their attendant allowance will invariably have to be surrendered by all who fail, in the next annual course, to fulfil the conditions and maintain the superiority by which these rewards were earned; and should the shooting of any battalion fall below the average, the prizes will be wholly withdrawn, and the issue of the additional pay suspended.

Should it be ascertained, either through the reports received from the Inspector of Musketry, or through any other source, that any undue advantage has been taken by a battalion in the execution of the several exercises in target and judging distance practices,—such, for instance, as counting ricochets—placing marks to aim at, to denote the allowance to be made for wind, &c., whereby the attainment of practical skill by the soldier would be defeated—firing at distances shorter than those enjoined by the regulations—or at a greater number of targets than are prescribed for the several distances,—departing in any way from the rules clearly defined for conducting the platoon and skirmishing practices,—or otherwise deviating from the spirit of the regulations published to ensure a uniformity of procedure in this particular throughout the army, and by which alone a fair comparative merit can be arrived at,—such battalion will not be eligible for the rewards granted by these regulations.

As it is of the utmost importance, in order to ensure a faithful record of the soldier's performances, and to protect the public from paying for merit undeserved, that the registers, and company's practice returns should be correctly kept, and be always forthcoming until authority has been received to dispose of them—if any irregularity should come under the notice of the Inspector of Musketry, whereby the integrity of the returns may be questioned,—such as erasures, corrections not initialed by an officer, absence of the signature either of the marker, or company-instructor, or sergeant acting in his stead, or loss of documents,—the battalion will be subject to forfeit the rewards herein prescribed.

Each portion of a regiment is allowed its proper proportion of company prizes, and the hundred prize-holding "marksmen" are to be distributed between service and depôt companies in the following manner; viz.:

10 service companies	90	100
2 depôt companies	10	

The extra pay is to be drawn, and the distinguishing badges are to be worn, for one year, commencing on the first day of the quarter succeeding that in which the annual report of practice is required to be made up, or as soon as the necessary authority is received.

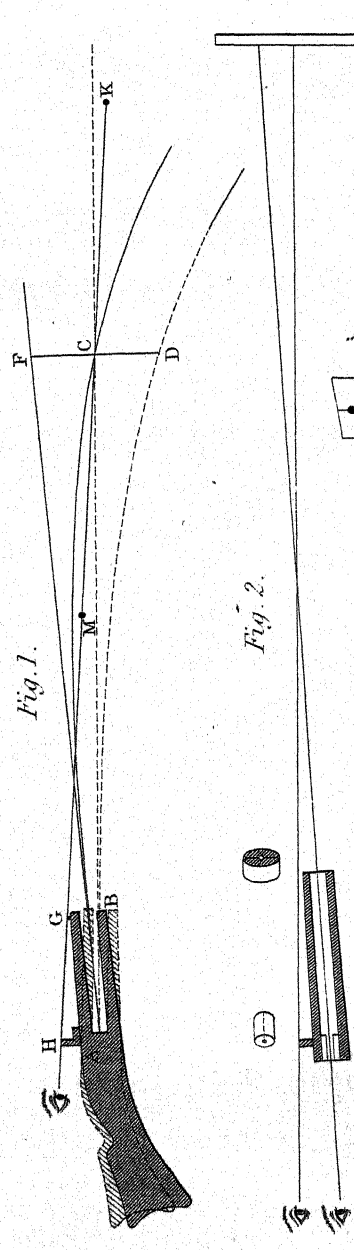


Fig. 1.

Fig. 2.

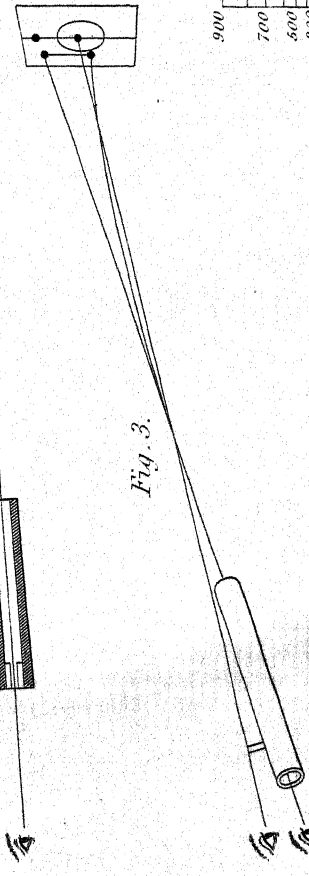


Fig. 3.

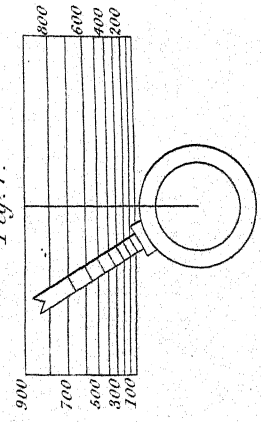


Fig. 4.

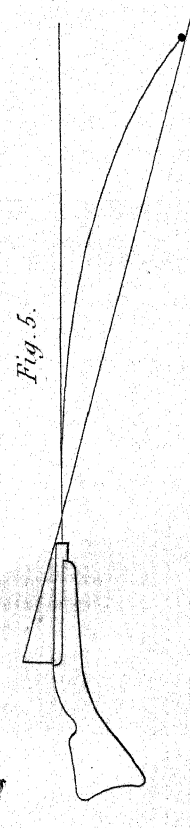


Fig. 5.

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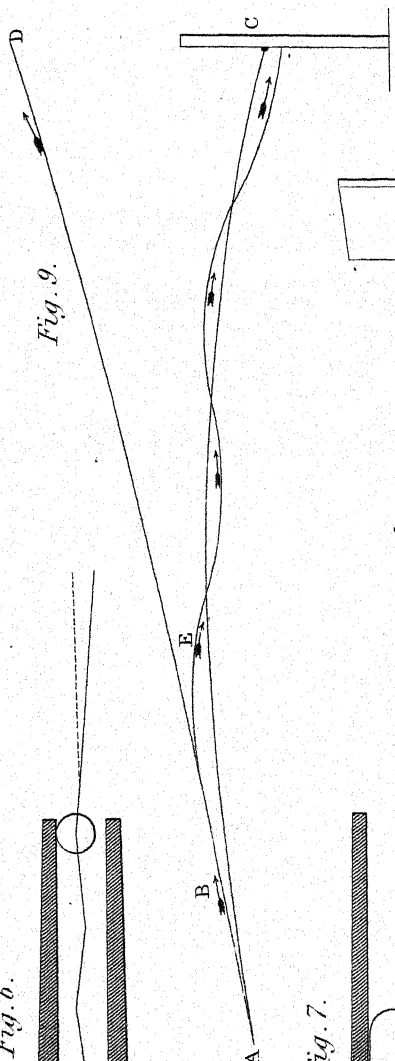


Fig. 9.

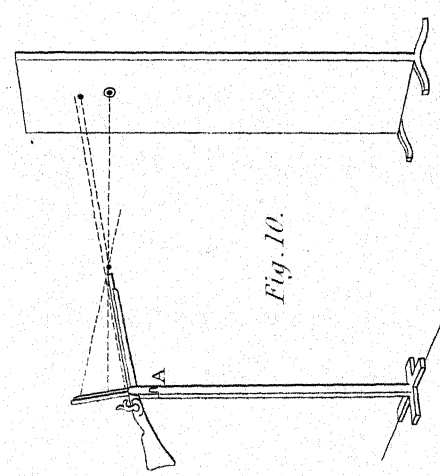


Fig. 10.

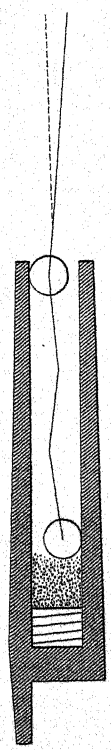


Fig. 6.

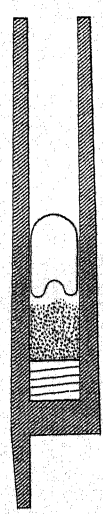


Fig. 7.

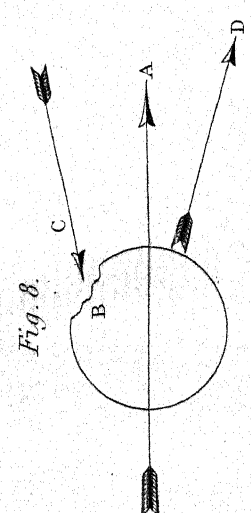


Fig. 8.

W.A. Beever, Sc.

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When a battalion is on active service in the field, or at a station where no range is available, the rewards are to be continued to those men in possession of them, until an opportunity occurs of their being challenged by another yearly course of instruction. A certificate from the commanding officer, verified by the general officer under whose command the battalion is serving, to the effect that under the circumstances above detailed (for under no other is the allowance to be continued beyond one year), the battalion has been prevented undergoing the prescribed annual course of rifle instruction for the year 18 , is to be forwarded to the Inspector-General of Musketry, for transmission to the Adjutant-General of the Forces, for the information of the General Commanding-in-Chief.

Recommendations for prizes are to be transmitted in triplicate according to the prescribed form with the annual musketry practice return sent to the Inspector-General of Musketry, by whom, after due examination, they will be forwarded, with his recommendation, to the Adjutant-General to the forces. When a notification of the General Commanding-in-Chief's approval is received the prizes are to be presented on parade, and the names of the prize-holders are to be published in regimental orders, and inserted in the "Final Classification Returns" kept in the companies' barrack-rooms.

In the event of a soldier who is in possession of the prize either as the "best shot of the battalion," or the "best shot of the company," becoming non-effective, the said prize is not to be awarded to another soldier.

The additional pay attaching to the prizes for good shooting is not to be drawn for a soldier when in confinement; but forfeitures under Clauses 28 and 29 of the Mutiny Act are not to deprive a man of the advantages attending a prize which he may gain in a subsequent year's course of instruction.

Badges of distinction, which are to be worked on cloth the colour of the facings of the battalion, will be supplied on application in the usual annual requisition for clothing. They are not to be issued from the quartermaster's store until authority is received for the award of the prizes.

OBSERVATORY, ASTRONOMICAL.

PART I.*

The purposes which it is intended that an Observatory shall fulfil, and the magnitude and description of the instruments with which it is designed to be furnished, will, as a general rule, regulate its plan and dimensions.

Observatories are either permanent and of solid structure, destined for the taking and recording of observations which may be of fundamental or general interest and inquiry; or temporary and portable, having principally for their object observations for local and particular purposes.

Considering, in the first place, 'Permanent Observatories,' a matter of primary and most important consideration, before proceeding with the construction of a design, will be a selection of a fitting site. This should be on an eminence, not greater than is sufficient to command a clear view of the horizon to the north and south, and over ground admitting of the erection, at suitable distances, of meridian marks in both directions; and it will be an additional advantage should the view be uninterrupted all round. The more solid and dry the nature of the soil is, the better; and it is

* By Lieut.-Colonel M'Kerlie, R.E.

essential that the site should be remote from all thoroughfares, particularly if for carriages.* The vicinity of swampy grounds, from which exhalations might arise, and of factories or other works, from the smoke of the chimneys of which annoying interruptions might be caused, should also be avoided.

The plan of arrangement of the building which has generally been adopted, and which is probably the most convenient, is to place the rooms intended for meridian instruments—viz. the transit, transit circle, and meridian or mural circle—in the centre, their transverse dimensions being truly perpendicular to the meridian line; whilst the rooms for instruments adapted for observing out of the meridian,—viz. the 'altitude and azimuth' and 'equatorial' instruments,—requiring rotative forms and a more commanding elevation, may be placed on the flanks. (See Plates I. II. III. IV.)

The dimensions and requirements of the several apartments will be noticed under the heads of the instruments for the reception of which they are intended.

The computing or waiting and attendants' rooms may be attached as wings, or perhaps more conveniently placed in the centre separating the meridian instrument rooms, where there is more than one. In these, fire-places may be constructed, which, the necessity of maintaining an uniform temperature and preventing draughts, render inadmissible in the observing-rooms.

Should the observatory be a national one, or of such important character as to require the constant and immediate presence of the observer, his residence may be attached as a wing, care being taken that its elevation does not break the sweep of the extra-meridional instruments.

In regard to the structure itself, of whatever material the circumstances of the locality may necessitate its being built, solidity and dryness should be the conditions sought to be attained. The foundation of the walls should be carried, if possible, as low as the bases of the piers of the instruments which they envelope: a stratum of asphalte should be placed at a sufficient distance below the floor wall-plate, to admit of a thorough system of ventilation being carried under the flooring; and above that level the external earth should not be allowed to touch the walls, but kept from them, if necessary, by a small covered area.

MERIDIAN INSTRUMENT ROOMS.

The Transit.—The purpose of the transit instrument requiring as a principal condition that it shall move in the plane of the meridian, the room destined to contain it will necessarily be placed rectangularly thereto; and its dimensions will necessarily be regulated by the size of the instrument.

In first-class observatories the focal lengths of the transit telescope object-glasses vary from 5 to 10 feet: the more ordinary length, however, is from 4 to 7 feet; that at the Royal Observatory, Greenwich, being the only existing one of the latter dimension. For the 5-feet instrument the apartment should not be less than 18 feet by 15; for the 7-feet, 22 feet by 16, the longer dimension being in the direction of the meridian; and the height may be from 14 to 16 feet in the centre.

The utmost attainable immobility is essential to obtain the best results from the transit instrument, and the pier carrying it, constructed of solid masonry, should be

* The public road passes close to the Royal Observatory at Chatham, and the noise caused by a cart rapidly passing is such as to render the beat of the clock inaudible; and the vibration caused by even a small party of men, in marching by, is such as to destroy the reflected image of a star in the mercury.

based at such a depth as may be necessary to insure this condition. All the earth between it and the external walls should be excavated and removed, none being suffered to rest against it, and the floor must not be permitted to be in contact. The best supports for the ends of the axis are solid stone prisms, of such a height above the floor as to enable the observer, reclining on his observing chair, to note the transit of stars in or near the zenith; and they should be selected, not only from the same quarry, but, if possible, cut from the same block.

The smaller class of transit instruments, those varying from 2 to 3 feet in length, are more generally considered as portable instruments, their chief purpose being to obtain exact time, whilst the larger instruments are principally employed in determining, with minute accuracy, the positions in right ascension of heavenly bodies.

These smaller instruments are usually mounted on cast-iron standard frames, supported on piers of stone;* but when permanently fixed, it would be desirable that even they should be mounted in the manner of the larger instruments, the tops of the supporting pillars being corbelled inwards (on account of the shortness of the axis), to afford room for the observer to pass between and beneath. The dimensions of the room for instruments of this class may be 12 or 13 feet from north to south, by 10 or 12 feet in breadth.

The indispensable accompaniment of the transit instrument is the astronomical clock. Its value depends on the regularity of its vibrations; and to secure it against external influences, it should be carried on a solid and independent stone pier, sunk to the same level as the basis of that which carries the transit itself. The best position for the clock is on the south side of the transit-room, and on the right hand of the observer, looking south.

To admit of the transit telescope being directed to any part of the meridian, an opening in its plane is required in the roof, and to be carried down through the side walls to a little below the level of the axis of the instrument. In order to bring the temperature of the internal as speedily as possible to that of the external air, and to prevent in-draughts, this opening, for the larger instruments, should be about $2\frac{1}{2}$ or 3 feet in width. The shutters to close it may be in two or more lengths, according to circumstances, and constructed so as to slide either entirely over the opening, or to meet in two pieces in the centre, motion being communicated from below by a winch and cordage; but in either case, most careful workmanship and an ample lap are necessary, to prevent leaking at the junctions. The vertical shutters, in one or more pieces, may either slide, or revolve in the ordinary manner on hinges.

For the smaller instruments, the aperture need not exceed 18 inches in width, and the shutters may be constructed to turn back on hinges, in the manner of the lid of a box. They will generally be most conveniently arranged in two pieces, meeting at the apex of the roof, thus admitting of the half on that side from which the wind blows being closed, and of observations being taken on the opposite side, which might otherwise be attended with difficulty; though, where the whole length does not exceed 10 or 12 feet, the fall being in one direction, the shutter may be in a single piece, with the advantage of being free from the liability to leak immediately over the instrument. In the Chatham Observatory the shutters are readily opened by means of a hook and ball, at the end of a short pole, fitting into an eye on the inside, and are kept open by sliding the foot of the pole into a socket screwed upon the window sill, and the vertical cut is very conveniently combined with the windows. The roof

Plate VI. figs. 1 & 2.

* Much inconvenience, if not difficulty, is found in observing transits near the zenith with the Chatham 30-inch instrument, which is mounted in this manner. The proposed mode of mounting is shewn in Plate V.

itself, covered with lead or zinc, ought not to have a greater fall than is necessary to carry off the rain; and the windows should, in the northern hemisphere, be placed on the north side of the room.

The Mural Meridian Circle.—This instrument, the use of which is to measure angular distances on the meridian, either with reference to a fixed horizontal or polar zero, is supported on the larger end of a strong conical axis, bearing in collars or y's fixed in a semi-cylindrical hollow cut in the mass of a solid stone wall or pier, placed with its length north and south; and close and parallel to one face of which (generally the eastern) the circle is required to revolve steadily in the plane of the meridian. To the face of the pier, also, are attached the micrometer microscopes for reading the graduated ring.

The same conditions of solidity of basis and of material, and of perfect insulation, are required for the pier of this, as for that of the transit instrument. The dimensions of the pier, above the floor-line, for the Greenwich mural circle, which is 6 feet in diameter, and may be considered as the standard in size, are 7 feet in length, 10 feet in height, and four feet in thickness. It is composed of four solid stones laid flat, one on the other, and from the under side of the third stone is cut the groove to receive the bearings of the axis, the steadiness of which, at the height of about 5 feet 6 inches above the floor, is thus secured by the heavy superincumbent mass. The mural circle is not adapted nor intended for transit observations, though attempts have been made so to apply it; but a good clock is a necessary appendage to its use, particularly when placed in a separate room, which it ought always to be. The size of the room, and also the arrangements, as regards the opening in the roof, the shutters, &c., should be the same, nearly, as those for a transit instrument of the same length of telescope.

The Transit Circle, combining the properties of both the transit and the mural circle, and requiring but one room and a single observer, may be employed to answer the purposes of both these instruments, requiring, each of them, separate rooms and observers. This instrument, carrying a transit telescope within a strongly framed and braced double circle, is supported by a double-coned axis, resting on a pair of stone pillars in the manner of a transit instrument. The same precautions are required as for that instrument, and the same arrangement of the room and roof. A transit circle of the diameter of 6 feet, understood to have been cast in one piece, and most strongly braced, is now being fixed in the Royal Observatory, Greenwich, and the micrometer microscopes, for reading the graduations, are placed within a narrow circle on the outer face of the western pier, radiating through holes bored in the stone to their respective points on the limb; an arrangement which combines great stability in the microscopes with much convenience to the observer.

With the smaller transit instruments, such as are considered portable, a meridian circle of 10 or 12 inches diameter, with a graduated level, is sometimes combined, admitting directly of the determination of latitude as well as of true time.

The foregoing instruments afford the data on which exact Astronomy is founded: with those of them working in altitude, the observation of the barometer and thermometer is indispensable, as materially influencing the results, and they will therefore necessarily form a part of the furniture of their apartments.

The instruments now to be considered, with the apartments to be prepared for their reception, are those adapted for observation out of the plane of the meridian; and of these the first to be mentioned, on account of its importance, is the *Altitude and Azimuth Instrument.*

The construction of this instrument admitting of its being moved freely in azimuth without materially disturbing its adjustments, provided it is firmly based, or in-

juring its property of giving accurate vertical measurements, its use is very comprehensive. When accurately adjusted to the plane of the meridian, which is its true astronomical position, it may be made to perform as a transit circle, giving right ascensions or true time, as well as altitudes and zenith distances, from which latter, latitude may be determined : though, with more correctness, from several observations near the meridian.

Time and latitude may also be obtained by observations in other positions of the instrument, as by absolute or equal altitudes or transits over the prime vertical, and the direction of the meridian line may also be very conveniently determined with it.

In the larger instruments of this description (the vertical circle of that in the Dublin Observatory being as much as 8 feet in diameter,—others of 5 and 3 feet), there are some differences in the arrangement of their supports, principally in the manner of steadying the upper pivot with which some of them are constructed. In the one recently erected in the Royal Observatory, Greenwich, the summit of the slightly tapering circular brick pier carrying it is spread out into the form of a tripod, on which rests a triangular frame of cast iron, forming the basis of a system of wrought rod-iron vertical triangles, crowned by a horizontal one (the angles all uniting), in the centre of which, formed by the junction of three bars radiating to its angles, is the socket to receive the upper pivot of the instrument. A solid circular block of stone in the centre of this truss carries the instrument, which is of great weight, solidity, and steadiness, and was especially designed by the Astronomer Royal for observing lunar altitudes out of the meridian. The diameter of both its vertical and azimuthal circles is 3 feet.

The smaller instruments, such as have a 15-inch or 18-inch vertical and horizontal circles, and which are portable and of very extended utility, are generally supported on foot-screws, three in number, resting in brass cups, either fastened on a masonry pier when in a permanent observatory, or on a wooden tripod stand when for temporary use in moving about. When mounted in a permanent observatory, the pier of support should be constructed with the same regard to solidity and insulation as has been before pointed out, and must be carried up to a sufficient height to admit of the instrument, when in place, having a complete command of the heavens over the transit-room, or other adjoining buildings.

For an 18-inch circle, the top of the pier may be 2′ by 3′ 6″, the larger dimension being placed north and south, to give space for a mercurial trough being placed for observations on the meridian by reflection. The form of apartment best adapted for the instrument is the circular, or, at all events, such a form as to receive a circular curb to carry a rotatory dome ; and as it is desirable that no unnecessary force should be required to put the dome in motion, the diameter should not be greater than the convenient working of the instrument demands. For an 18-inch circle, 10 or 12 feet will be sufficient ; for a 3-feet circle, 14 or 15 feet.

The rotatory roof, or dome, may be either conical or spherical :* the former, however, is much the simpler and more economical construction, and the shutters can be much more easily applied to the cut which is necessary on one side of it, extending also about a foot or so across the apex. The upper part may be separately opened for zenith observations, and closed by a shutter in the manner shown in figs. 1 and 2, Plate IV. The lower part may be conveniently opened and closed by a rod or hook, as shown in figs. 3 and 4, Plate VI. ; and as a means of increased lightness, these

* The roof over the Greenwich instrument is cylindrical, with a nearly flat top, and is 12 feet in diameter.

shutters may be covered with painted canvas, the rest of the roof being covered with zinc (as is the case in the Chatham Observatory) or copper. There are several methods of supporting the roof so as to obtain a circular motion, as on fixed rollers, on balls moving in square channels, or on balls running freely in concave channels, both over and under the balls. The second method is shown by fig. 4, Plate VII., being that used for the altitude and azimuth room of the Chatham Observatory, but the last method is that which produces by far the freest motion. Fig. 2, Plate VII., shows the section of the channels, on this principle, of the 15-feet dome over the Chatham equatorial. The dome over the large equatorial telescope recently mounted at Cambridge by the Astronomer Royal, which is 26 feet in diameter, in form a flatter one resting on the frustrum of a sharper cone, and framed of wrought iron braced with hoop-iron and covered with zinc, is also carried in this manner, and revolves with perfect freedom. Fig. 5, Plate VII., is a section of its channels and balls. The radius of the sunken surface may be twice the diameter of the balls, of which six is the proper number to employ.

To give motion to the smaller domes, not exceeding 12 feet in diameter, the force of the hand is sufficient, and may be applied either to pins or handles let into the inner face of the curb; or should that be inconveniently high, to a fixed handle brought down to a suitable position (figs. 3 and 4, Plate VII.). For the larger domes, the application of levers and other mechanical contrivances to communicate quick or slow motion is required. Figs. 1 and 2, plate VII., show the form of the levers for the Chatham equatorial dome.

It may be a necessary precaution to secure such domes against liability to displacement in storms or gales of wind, and for this purpose, hold-fasts or other means must be employed, which there can be no difficulty in contriving.

The *Repeating Circle*, by Borda, is an instrument which, as it requires nearly the same accommodation as the altitude and azimuth instrument of the same size, may be mentioned in conjunction with it. The principal difference is, that the supporting pier must be somewhat broader, to give space for an illuminating lamp on a separate stand. The chief astronomical use of this instrument is to observe circum-meridian altitudes for latitude. Time may also be obtained with it by equal or absolute altitudes. Its perfect manipulation, however, demands two observers, and it is altogether an instrument but little known or used in this country.

The *Equatorial* is the next instrument for which provision of space in a permanent observatory is to be considered. The form and position of the supports of this instrument will depend on the nature of its construction, which is of two distinct kinds; one, in which the telescope is carried, with the declination circle, on a transverse axis at the end of, and at right angles to, a long polar axis; and the other, in which the telescope is carried in the manner of a transit, between the cheeks of a frame-work forming the polar axis, pivots being fixed in the centres of its extremities, and long enough to permit the telescope to revolve completely within it. A stone bed of a suitable length for the polar axis, and having its upper surface dressed to the degree of slope of the latitude of the place, may form the support, according to circumstances, of the first form of construction. The second form, admitting of both larger horary and declination circles, and having other advantages, is that most generally adopted in England. It is supported,—the lower pivot in a socket let into a stone bed, and the upper in a collar in a fixed metal frame-work. The use of this instrument is, to determine the place of celestial phenomena by reference to its graduated circles. Great reliance cannot, however, generally be placed on the exactness of its results, unless used differentially. The same degree of perfection of stability in its supports is not, therefore, demanded, though this must still remain a point of importance.

Like the altitude and azimuth instrument, the equatorial must be mounted high enough to command the heavens, and under a revolving roof.

The size of the instrument, and the form of its mounting, with a due regard to sufficient accommodation and the easy working of the dome, will regulate the diameter of the apartment.

When great optical power for astronomical investigations, for the observation of occultations, of eclipses, of Jupiter's satellites, or for micrometrical measurements of the planets, &c., is required, larger telescopes must necessarily be employed. These are generally equatorially mounted, and carried by clock-work, the graduated circles being, however, more for finding objects than for determining their positions; and when advantageous sites offer, they may be placed (as they frequently are) in isolated buildings specially constructed for them.

The instruments which have now been mentioned comprise all those with which modern observatories are ordinarily furnished. The *Zenith Sector* has not been referred to, as it is not understood to be now in use in any permanent observatory, and the recent construction of the instrument by the Astronomer Royal, for the Ordnance Survey, is considered more as of a portable character. The great reflecting telescopes, as Sir W. Herschel's, Lord Rosse's, &c., it is also unnecessary to do more than merely mention.

Portable Observatories now remain to be described. Their construction will differ according to the purpose of the instrument which they are intended to give cover to, and may be considered as of three classes; namely for the altitude and azimuth instrument, the transit, and the zenith sector, the principal instruments which are portably employed.

For the first (the altitude and azimuth instrument), the observatory which was designed and used by Sir John Herschel at the Cape supplies all that can be required, and it also suffices for the transit instrument.

The observatory used on the Ordnance Survey for the first-class theodolites (described by Major Robinson, R.E., in Part III., and figured in Plates VIII. and IX.) may also, with a little modification in the roof, be adapted to this instrument when circum-meridian observations only are desired. For the other instruments, the transit and zenith sector, the observatories used on the Ordnance Survey (also described by Major Robinson, and illustrated in Plates XII. and XIII.) are very complete.

With these examples, then, there can be no difficulty in at any time designing for any particular instrument a portable shelter. It seems only further necessary to remark, that the floors of each of these observatories must be kept quite clear of the stand of the instrument, which, were it practicable, it would be desirable always to base on solid rock; but as this cannot often be the case, stout stakes should be driven, when possible, firmly into the ground, and the heads prepared to receive the feet of the tripod.

Although this paper was intended to have reference to the construction of Observatories only, and not to practical observing; yet, as it has been thought it might be useful to add some memoranda on this subject, the adjustment of such of the instruments as are most frequently met with, the corrections for residual errors, and the formulæ for the reduction of observations, are briefly touched on, and the forms for recording observations used at the Chatham Observatory are given.

The purpose of the transit, as has been stated, is chiefly to obtain true time, and to determine right ascensions. To this end it is necessary that the centre wire of the telescope should be vertical, and the line of sight through it perpendicular to the axis,

or in collimation ; also that the axis should be level, and the telescope revolve in the plane of the meridian. The instrument being brought approximately into position, the adjustments are completed by means of proper screws provided for the purpose; but perfect adjustment cannot be expected to be obtained, and remaining errors must be allowed for by computation.

For level, the striding level must be applied before and after each observation, and the difference between the sum of the east and the sum of the west readings being taken then, $\frac{1}{4}$ of that difference $\times \frac{\text{sin. alt.}}{\text{cos. declin}^{n}.}$ of star observed = the correction to be applied with its proper sign + or — ; and as the divisions of scale on the level tubes are usually in spaces of $1\frac{1}{2}''$, the correction will be in 10ths of seconds of time.

For collimation, observe the passage of a star of very high declination over the 1st, 2nd, and 3rd wires, and again, in a reversed position of the instrument, over the 4th and 5th, which in the 1st position were the 2nd and 1st, noting the level readings before and after each passage : then the difference between the mean of the 1st, 2nd, 4th, and 5th, and the 3rd, each corrected for level, is the error due to collimation; which error × by cos. declination of star observed is the collimation error or effect on an equatorial star ; the correction for any other star = collimation error × secant of declination of that star. Attention must of course be paid to the signs.

For azimuth, transits of two stars, either on opposite sides of the zenith remote from each other as possible, or on opposite sides of the pole, but on the same side of the zenith, if each be near the pole, the more accurate, are to be observed. Then, the sum of the errors produced on the transits (each corrected for level and collimation), ascertained by comparison with the proper interval, will be the effect of azimuthal deviation. Calculate the result of 1^{s} azimuth error on each star = $\frac{\text{cos. alt.}}{\text{cos. declin}^{n}.}$ then the deviation = the observed sum of the errors divided by the sums of the two results. The correction for deviation for any star = $\frac{\text{cos. alt.}}{\text{cos. declin}^{n}.} \times$ by the deviation. The azimuth error may be obtained by transits of stars in other positions; in which case, however, it will be the difference instead of the sum of the errors on the interval. It may also be obtained by observing the transits of a circumpolar star at its upper and lower culmination; in which case, the difference between the observed interval and 12 hours will be the sum of the effects on the upper and lower transits produced by the azimuthal deviation. There are also other errors, arising from the intervals between the wires of the telescope being unequal, and also for inequality of pivots, which must be ascertained and allowed for.

In observing with the transit, whilst the star or other object is steadily viewed, the instant of its passage over each wire is noted by listening to and counting the beat of the clock ; and the mean of the wires, corrected for the instrumental errors, is the true clock time of passage, the error of which is thus ascertained, and, by observations extending over several nights, its rate.

The form of registration used at Chatham is as follows :—

Transits over the Meridian of the Observatory of the Royal Engineers' Establishment, Chatham.

No. of Observation.	Date.	Illuminated end, East or West.	Inclination of axis. E. end highest— W. end do. +		Object.	Zenith distance.	North or South.	Telescope Wires.					Mean.	Corrections.				True Passage.	Clocks.		No. of Days.	Remarks.
			Indication of Level.	Inequality of Pivots.				I.	II.	Centre.	IV.	V.		To Centre Wire.	Collimation.	Inclination.	Azimuth.		Error.	Rate.		
	1849.		s.	s.		° ′		s. 40-38	s. 51-33	H. M. S. 1 2 28	s.	s.	H. M. S.					H. M. S.				Collimation error deduced = 0s·038 ; + when illuminated end is East, and star above Pole.
532	Jan. 22.	E E E W Level.	+ ·07 + ·02 + ·02 + ·12	+ ·04 — ·04	Polaris.	37 5	N.				13-20	24-16										
533	,,	E.	— ·2	+ ·04	Aldebaran.	35 11	S.	12	30	4 25 47	5	23	4 25 47·4		— ·06	— ·13	— 1·39	4 25 45·82	— 99·71			
534	,,	E.	Level.	+ ·04	δ Orionis.	51 47	S.	16	33	5 22 49·5	6-5	23-5	5 22 49·7		— ·06	0	— 1·82	5 22 47·82	— 99·89			
535	,,	E.	— ·05 — ·15 — ·15 — ·1 — ·1	+ ·04	ε Ursæ Minoris.	46 20	N.	55-56	58-3	5 0 9	2-15	4-22	5 0 9		+ ·47	+ ·35	— 12·43	4 59 57·3	— 92·88			Below the Pole.
536	,,	E.	Level.	+ ·04	ε Orionis.	52 40	S.	31	48-5	5 27 5·5	22	39	5 27 5·2		— ·06		— 16·7	5 27 3·47	— 99·67	+ ·10	7	
537	,,																					

Note.—The forms here given, including the above, were arranged for the Chatham Observatory by Captain (now Colonel) Harness, R.E., and the formulæ for corrections and reductions are also principally from his notes.

To ascertain the error of other time-keepers by comparison with the clock which is thus noted, a most accurate method is given by the Astronomer Royal in Part II., and the following is the daily form of reduction for error of a mean time chronometer at Chatham :

R. E. Observatory,
Jan. 24, 1849.

Clock's error 44ˢ·41 slow.
Rate . . . ·43 losing.

H.	M.	S.	
20	11	46·90	sidereal time at mean noon at Greenwich.
		·35	correction for longitude.
20	11	46·55	sidereal time at mean noon at Observatory.
17	13		clock at time of comparison with chronometer.
2	58	46·55	difference.
1	59	40·34	mean equivalents for above difference.
	57	50·49	
		45·87	
		0·54	
2	58	17·24	mean interval from noon by clock.
12			
9	1	42·76	mean time A.M. by clock.
9	0	95·	time by chronometer.
	1	37·76	chronometer slow.
		44·41	clock slow.
	2	22·17	error of chronometer, slow.

The reduction of observations will be considerably facilitated by preparing a table of corrections for 15″ or 1ˢ of each form of error for every $\frac{1}{2}$ or $\frac{1}{4}$ degree of declination computed to the latitude of the place ; and it will also be found convenient to prepare a table of the true and apparent altitudes and zenith distances, as well as the right ascensions of the principal stars.

By observations of lunar transits in conjunction with the moon culminating stars which are given for each day on which the moon is visible throughout the year in the Nautical Almanac, longitude may be ascertained, accurately by direct comparison with corresponding transits over an observatory whose longitude is known, and approximately from the computed transits over the Greenwich Observatory, as given in the Nautical Almanac.

The transit instrument, when portable, may also be applied to obtaining latitude with considerable accuracy, by placing it in the plane of the prime vertical, or at right angles to the meridian. The observation for this purpose consists in noting the transit of a star over the prime vertical both to the east and west—then, the cos. of $\frac{1}{2}$ the interval in sidereal time reduced to arc, × by the cot. declination of the star, = cot. of the latitude. In order that the time-keeper may have but a short interval to measure, stars should be chosen for observation whose declination is but a few degrees less than the latitude, and the approximate altitude and hour-angle from

the meridian may be computed, assuming a value for the latitude, from the formulæ sin. alt. $= \frac{\text{sin. declin}^{n}.}{\text{sin. lat.}}$ cos. hour angle $= \frac{\text{cot. lat.}}{\text{cot. declin}^{n}.}$. By reversing the instrument between the east and west observations, the error of collimation is counteracted, and a deviation of a few minutes from the prime vertical will not be of any material importance. The error in the level, therefore, need only be observed, producing a similar amount of error in the result.

The use of the Altitude and Azimuth instrument has previously been explained and requires that the vertical circle and axis of the telescope shall in all positions of the instrument describe a great circle. The adjustments are—1st, To set the vertical axis perpendicular to the horizon. This is effected approximately by the ground levels attached to the lower circle, and more accurately by the graduated level hung to the arms carrying the microscopes, and by the foot-screws. 2ndly, The horizontal axis of the upper circle and telescope must be set level. This is done by passing the striding level between the bars of the circle, and reversing it. 3rdly, The micrometer microscopes must be brought into a diameter of the circle, and adjusted to distinct vision and correct measure of the graduations on the limb. 4thly, The optical adjustments of the telescope are to be perfected, and the central wire caused to describe a great circle ; and finally, the micrometer microscopes are to be re-adjusted, and the error of collimation in altitude to be removed or ascertained.

It is not, however, to be expected that the errors can be entirely destroyed by adjustment. The indications of the level must be noted in reversed positions for all observations, and the error, $= \frac{1}{4}$ the difference of the sums of the readings (face of instrument right and left), allowed for ; and in collimation, the errors both in altitude and azimuth may be eliminated by making the observation in reversed position, that is, with the face of the instrument both right and left, which should always be done when possible.

There are several methods by which latitude may be obtained by means of the altitude and azimuth instrument.

1st, By observing the greatest and least altitude of a circumpolar star. The mean of the observations, each corrected for refraction, &c., will be the latitude. In the northern hemisphere, Polaris and δ Ursæ Minoris are excellent objects for this purpose. 2ndly, By observation of the meridian altitude of any heavenly body whose declination is known ; which is the method most generally adopted : and 3rdly, as the result of both the previous methods is dependent on the accuracy of a single observation, with greater precision, probably, by circum-meridian observations of a star or other object, that is, by taking several altitudes before, and an equal number after passing the meridian, and as nearly as possible at equal distances from it, noting the time of each. The instrument should be reversed between the eastern and western observations, thus destroying the effect of collimation error ; and the observations should be limited to not more that 15 minutes on each side the meridian when the zenith distance exceeds 30°, and to not more than 8 minutes if less.

The correction to be applied to the altitude, or

$$\text{Zen. dist.} = \frac{\text{sin. co-lat. sin. Polar dist.}}{\text{sin. zen. dist.} \times \text{sin. } 1''} \times \text{vers P},$$

in which an approximate value of the co-latitude is assumed, and the other quantities for each observation being the same, the mean of the versines of the hour angles (P) has only to be applied to the general formula.

The form of record for observations with the altitude and azimuth is as follows :

ALTITUDE AND AZIMUTH INSTRUMENT.

Observations on or near the Meridian of the Observatory of the Royal Engineers' Establishment, Chatham.

No. of Observation.	Date.	Object.	Approximate zenith distance.	North or South.	Direct or Reflected.	Face of instrument E. or W.	Readings.								Error of Time-keeper.	Barometer.	Thermometer.	Remarks.
							Time-keeper.	Level.		Microscopes.				Mean.				
								Eye-end.	Object-end.	A.		B.						
										Reading.	Corr. for Run.	Reading.	Corr. for Run.					
			° ′				H.M.S.			° ′ ″	″	″	″	H.M.S.	S.	in.	°	

Latitude may be obtained also with this instrument by observations of the transits of stars over the prime vertical, as with the transit instrument, and also by observations of Polaris out of the meridian, of which latter method a description, with Tables, is given in the Nautical Almanac.

To obtain time with this instrument, two methods may be employed: 1st, by a single altitude on or near the prime vertical. In this case the latitude is supposed to be known, and the hour-angle, and consequently the time, is obtained from the formula.

$$\sin.\ \frac{Z\,P\,S}{2} = \sqrt{\frac{\sin.\ (S - P\,S)\ .\ \sin.\ (S - Z\,P)}{\sin.\ P\,S\ .\ \sin.\ Z\,P}},$$

in which Z P S is the hour-angle formed by the meridian of the object and of the observer, P S the co-declination of the object, Z P the co-latitude, and Z S the co-altitude,

$$S\ \text{being} = \frac{Z\,S + P\,S + Z\,P}{2}.$$

2ndly, by equal altitudes, which method is independent of the latitude, one-half the observed interval between the star attaining equal altitudes being the time of its passing the meridian, from which the error of the time-keeper becomes known. If the object be one whose declination alters during the interval, as the sun, or a planet, correction is necessary on this account

$$= \left(\text{cot. } Z\,P\ .\ \text{cosec.}\frac{P}{2} - \text{cot. } P\,S\ .\ \text{cot.}\ \frac{P}{2}\right)d,$$

$\frac{P}{2}$ being = the half-interval corrected; but which may be assumed as half the observed interval, without sensible error, and d = the change in declination.

The direction of the meridian may be found by observing the greatest eastern and western elongations of a circumpolar star, the mean of the readings of which on the horizontal limb will be the reading of the direction of the meridian; also by observing the readings of the positions in which a star attains equal altitudes, and also by

observation of a single altitude, when, the latitude being known, the azimuth angle may be computed.

In regard to the repeating circle by Borda, its principal astronomical use has been stated to be in observing circum-meridian zenith distances, or, by reflection, altitudes. The adjustments consist in making the upright axis perpendicular by means of the main level attached to the back of the circle, and the plane of the circle vertical by the small cross level on the counterpoise end of its axis. The observations are made thus : the telescope is clamped by means of one of the arms carrying the verniers to the circle, and the object bisected by the slow-motion screw of the circle, whilst the bubble of the level is kept near the centre of its run, and its indication noted the moment the observation is complete. The verniers are then to be read, and the instrument turned 180° in azimuth, and the telescope, by unclamping the vernier-plate, is brought over the zenith, again clamped, and the object again bisected by the telescope slow-motion screw, whilst the level is again read. Twice the zenith distance of the object has thus evidently been passed over. The time of each observation must be carefully noted. This process may be repeated as often as may be thought fit, and the readings of the first and last observations only being taken, their difference divided by twice the number of repetitions will be the zenith distance, to which must be applied the correction for level, = the difference between the sums of the object and eye-end readings divided by twice the number of observations, — if the object-end be the greater, and + if the eye-end. The following is the form for recording the observations :

REPEATING CIRCLE.

Observations on or near the Meridian of the Royal Engineers' Observatory, Chatham.

No. of Observation.	Date.	Object.	Approximate zenith distance.	North or South.	Direct or Reflected.	Face of instrument, Left or Right.	Readings.								Error of Time-keeper.	Barometer.	Thermometer.	Remarks.
							Time-keeper.	Level.		Verniers.								
								Eye-end.	Object-end.	A.	B.	C.	D.	Mean.				
			° ′				H.M.S.	″	″	° ′ ″				° ′ ″	S.	in.	°	

The only other instrument which will now be referred to is the *Zenith Sector*, constructed within the last few years for the Ordnance Survey. In determining latitudes in the field, its results are understood to have been highly satisfactory. Having been placed in the plane of the meridian, and the axis, which has three levels attached to it, made vertical, or nearly so, the observations are made by setting the telescope nearly for a star, reading the micrometer microscopes by the sectors, and then completing the observation by the wire micrometer attached to the eye-end of the telescope, at the same time noting the level readings and the time. The instrument is then turned half-round, and the observation repeated; completing the bisection on this side by the tangent-screw, again noting the levels and time, and lastly, the readings of the micrometer microscopes : the double zenith distance is thus obtained.

As it is conceived that in field operations they may be of great value, a part of the instructions which were furnished to the Officers of the Royal Engineers who were engaged in the survey and astronomical determination of points in the Boundary between the United States and Canada, in 1843-5, by the Astronomer Royal, are, with his permission, given in Part II. J. G. M^cK.

PART II.—ON THE PROPER MANNER OF COMPARING CHRONOMETERS AND OTHER TIME-KEEPERS.*

A. I. *General Rule.*

The most important of all things regarding the accurate use of transits and chronometers, is to acquire the habit of counting the beats of the clock, or the alternate beats of a half-seconds chronometer, without looking at its face while writing, or while moving about, or through any disturbance.

A. II. *To compare a solar half-seconds chronometer with a sidereal clock, by coincidence of beats.*

Place the chronometer on a stool or table near the clock; hold a memorandum-book in one hand and a pencil in the other. Listen carefully to both the clock and the chronometer, keeping the eye fixed on the seconds-hand of the chronometer.

The beats of the two instruments will at first, perhaps, follow in no distinct order; but as the clock gains on the chronometer it will be found that they approach the state of beating simultaneously. When you are satisfied that they are beating simultaneously, you must mentally *select* one of the beats which you assume to be perfectly coincident, (as the precise time will be doubtful during a few seconds), and immediately write down that second (with its half-second, if it happens to be a half-second) in the memorandum-book, and at the same time begin counting the beats of the clock, 1, 2, 3, 4, &c. Then write the minutes from the chronometer face, and then the hour (still continuing to count the beats of the clock), and then turn your eye to the seconds-hand of the clock; continue counting till the seconds-hand is at a conspicuous place (the beginning of the minutes or of one of the tens); and then stop. Write down, first the seconds that you have counted; secondly, the seconds on the clock face at which you stopped; thirdly, the minutes from the clock; and fourthly, its hour. Then the comparison will stand thus: chronometer, $1^h\ 16^m\ 22^s{\cdot}5$ = clock, $11^h\ 42^m\ 20^s$ — 27, where 27 is supposed to be the number of beats counted from the selected coincidence.

In comparing a half-seconds solar with a half-seconds sidereal chronometer, the process is the same, counting every alternate beat of the sidereal chronometer.

A. III. *To compare a pocket chronometer beating five times in two seconds, and going mean solar time nearly, with a sidereal clock, by coincidence of beats.*

The seconds-hand of a pocket chronometer making 5 beats in 2 seconds, advances $0^s{\cdot}4$ at each beat. It will not, therefore, coincide at every second with a mark on the chronometer face, but at every alternate second. In order to see distinctly at which second the coincidence takes place (so as to avoid the error of $0^s{\cdot}4$), and also to correct the usual error in the division of the chronometer face, it will be expedient to mark the face with ink, correctly, at every alternate second.

Suppose, then, the face is either so correct as evidently not to require this, or that

* Selected, by permission, from notes by Professor G. B. Airey, Astronomer Royal.

the correction is made by ink marks. Then the process of comparison with the sidereal clock will be exactly the same as that for a half-seconds chronometer. It will, however, be a little more troublesome, because there are always a number of beats at small intervals which disturb the ear, and because in most cases the chronometer time will be a fraction of a second, which requires a little care; thus, if the chronometer reading be one which follows 26—it may be 26·4, 26·8, 27·2, 27·6, or 28, and hence four out of five are at fractions of a second.

The comparison of a $\frac{2}{3}$-seconds solar chronometer with a 2-seconds sidereal chronometer will be made in the same way, always counting the alternate beats of the sidereal chronometer (as said before under No. II.).

There are some chronometers which beat 8 times in 3 seconds: with these it would be requisite to mark the face at every 3 seconds, and then supposing a coincidence to be at one of the beats following 21^s, it would be at $21\frac{3}{8}$, $21\frac{6}{8}$, $22\frac{1}{8}$, $22\frac{4}{8}$, $22\frac{7}{8}$, $23\frac{2}{8}$, $23\frac{5}{8}$, 24. This is therefore very troublesome.

(I.) *To adjust a portable transit instrument.*

1. As early as possible, correct very carefully the error of collimation, and make yourself quite sure that every screw about the object-glass and wire-frame is quite tight. This may be done by the use of any mark in any position, at a distance where it can be distinctly seen. The best mark will be a hole in a tin plate with a reflector behind it.

2. At the same time, by reversing the transit several times, and levelling carefully each time, ascertain whether there is any apparent irregularity of the pivots; and remember that half the apparent error is in future always to be left in the position to which the axis is raised.

3. As soon as stars appear, look for Polaris and direct the transit to him, taking care that the axis is very nearly level. With the time by account find his hour-angle east or west of the meridian; with this and the latitude by account find his azimuth at the observation. Bring the transit to a horizontal position, and let an assistant carry a lamp to any convenient distance, and move it (by signal) till it is under the wire; measure the distance roughly (as by pacing), and with this distance as radius, compute the value of the azimuth, and shift the lamp by this quantity, and fix it for a temporary meridian mark.

4. Direct the transit to this mark, and level it carefully; observe the transit of a star as near the zenith as possible, and you will have the correction of your chronometer to sidereal time very nearly.

5. With this correction compute the time when any of the near circumpolar stars ought to pass the middle wire, λ Ursæ Minoris, Polaris, 51 Cephei, ϵ or ζ Ursæ Minoris, or even γ Cephei, above or below the pole (Polaris is the best); and as the star approaches the wire, knowing the time in which it passes from wire to wire, you will be able to see whether it will reach the middle wire about the proper time. If it is likely to be so far from it that the adjustment screws will not bring it right, shift the feet of the stand immediately (this must be done rapidly and steadily), till it is very nearly right; then level the transit, and with the adjusting screws place the wire on the star at the proper time.

6. This may be done by degrees, by using different stars (as they pass successively) for successive approximations. For this purpose it will be convenient to have ready at hand, a table with the circumpolar upper and lower positions. Set down in the mingled order in which their upper and lower transits occur, with the R. A. for that day placed opposite, and another column in which the R.A. corrected for chronometer error may be inserted as soon as a zenith star has been observed.

7. While waiting for these circumpolar stars, if a low Nautical Almanac star should pass, its time may be prepared, and an endeavour made to plant the wire on it at the instant: but this is not to be done after a circumpolar star has been observed, because the circumpolar determinations are the more accurate.

8. As the successive corrections of positions are made, observe any stars that pass pretty high, and you will get more and more accurate corrections of the chronometer for use with the next circumpolar star.

9. After every shift, level the transit carefully before using it for another star.

10. In this way you will in two or three hours get the transit into the meridian with scarcely an appreciable error remaining. When that is done, shift the temporary position of the meridian mark delicately, and even fix one at a considerable distance (by signal) exactly under the wire. You can then observe a few stars for chronometer error, and your transit may be considered as adjusted.

11. It will be prudent never to shift this mark again, but always to bring the transit upon it, and level carefully before every observation. Then consider the transit as having an azimuthal error Z.″ by which, when directed to the pole, it points too much to the west. Then prepare for all the stars which you are going to observe, small tables of the numbers—

$$\frac{\text{sin. star's zenith distance}}{15 \times \text{sin. star's N P D}},$$

negative between the zenith and the pole, and positive for other parts of the meridian.

By comparing the clock errors given by the transits of circumpolar stars with those given by any other, or even by comparing the clock errors given by zenith stars with those given by low stars, the difference of these clock errors (containing a multiple of Z.) will determine Z.; and then this value of Z., multiplied by the factor for each star, must be applied to the observed transit of that star.

12. In a favourable night, the transit should be reversed, and some transits of circumpolar stars and clock stars be observed with illuminated end east as well as illuminated end west, and the mean should be used. The collimation should not be touched between, but the axis should be carefully levelled.

13. If the meridian mark mentioned in (11) is well guarded, so that it is certain that it has never been moved, and is distinctly seen, the transit should by the azimuth screws be always brought upon it; but if there is any doubt upon this point, the transit should not be moved, but the position of the mark right or left, and its distance by estimation (in thicknesses of the wires) should be noted very frequently. In any case, this is the safe way when the error is small.

14. As a general rule in observing, level before and after every observation, if the time permits; observe circumpolar stars as often as possible,—one to every clock star, if possible.

(II.) *To determine the latitude by the transit.*

1. Suppose that the transit instrument has been adjusted to the meridian, and that the error of the chronometer has been obtained as has been described in instructions (1), it will be desirable to leave the pedestal of the transit for its proper transit observations undisturbed, and to take a new position for the new observations in the meridian line passing through the old position, which will be easily traced by means of the meridian mark.

2. Plant a common theodolite in the new position, observe the meridian mark, and then turn the telescope 90°, and thus fix on a mark as E. or W. mark. An azimuth

compass will probably suffice, if there is no theodolite at hand (for extreme accuracy is not required, and observations to be made in the manner hereafter described will give the means of correcting the results); but trouble will be saved by fixing the azimuth as precisely as possible.

3. Plant the transit instrument on the site of the theodolite, and adjust it to the new E. or W. mark, and level it very carefully.

4. Prepare a list of stars whose declination is less than the latitude of the place, but by as small quantity as possible. There are few stars in the Nautical Almanac in this predicament, and you may be compelled to use other Catalogue stars. Compute roughly the zenith distance at which they will pass the prime vertical by the formula

$$\text{cos. Z D} = \frac{\text{sin. declination}}{\text{sin. latitude}},$$

and the hour-angle at which they will pass the prime vertical by the formula

$$\text{cos. hour-angle} = \frac{\text{tan. declination}}{\text{tan. latitude}}.$$

By means of these the time and position will be sufficiently well known. But if the latitude is very uncertain, it will be necessary to look out some minutes before the time computed.

5. The observation then will consist in simply noting the chronometer time at which the star passes the wires (taking the mean as usual): as the course of the star will be very oblique, it will be necessary to move the transit so that the star shall cross each wire at that part at which transits are usually observed.

This observation must be made when the star crosses the prime vertical both east and west of the meridian.

7. The observation being made, and corrected for chronometer error and rate, the mean time between the time at the east and the time at the west transit will be nearly (but perhaps not exactly) the same as the R. A. of the star. If it is greater than the R. A., it shows that the supposed E. mark was too far south, if the latitude of the station is north; or too far north, if the latitude of the station is south. This difference ought to be the same from different stars: convert it into arc. Then the error of azimuth of the mark will be found by the formula

$$\text{tan. error of azimuth} = \text{tan. converted difference} \times \text{by the sin. latitude.}$$

By this formula the place of the mark can be altered, if it is thought necessary.

8. Half the difference between the east transit and the west transit is the star's observed hour-angle at passing the prime vertical. Then the latitude is determined at once by this formula:

$$\text{tan. lat.} = \frac{\text{tan. star's declination}}{\text{cos. observed hour-angle}}.$$

This ought to result the same from different stars.

9. The latitude, or mean of all these latitudes, is to be corrected by the formula

$$\text{tan. true diff.} = \text{tan. approx. latitude} \times \text{cos. converted difference.}$$

It will be scarcely altered by this computation, except the error of the mark be very considerable.

10. If these operations are continued for several nights, it will be proper to use the transit alternately illuminated end east and west, and not to meddle with the collimation error or adjustment.

11. The most scrupulous attention must be given to the levelling.

(III.) *To determine the latitude with the altitude and azimuth instrument.*

1. Adjust the axis *nearly* to verticality, and the cross axis *nearly* to horizontality. Accurate adjustment is not at all necessary.

2. Direct the telescope to the star, and bisect the star upon the middle horizontal wire, and note the time of the observation. Theoretically speaking, the star may be observed in any part of its course; but practically, any star, except the three circumpolar stars, should be observed within a few minutes of the time of its passing the meridian.

3. Read the large divisions with the pointer, and read the two microscopes, A and B, and enter the readings in your book; and read the level, *right hand* and *left hand*, and enter them in the book by those names, and not by north and south.

4. Then turn the instrument 180° in azimuth round its vertical axis, and go through the same operation.

5. Revert to the first position, and make an observation; and return to the second position, and make an observation; and so often as you think fit.

6. Read the barometer and thermometer.

The observation is now complete.

7. Add together for the first operation,—

Reading of A.
Reading of B.
Equivalent for left-hand level.*
Subtract equivalent for right-hand level.
Divide the remainder by 2.
Apply the pointer reading.

This gives the uncorrected circle reading of A.

8. Do the same for second observations (noting, however, that in the present state of divisions it will be sometimes necessary to increase one value by 90°), and you will have the uncorrected circle reading of second observation.

These are necessary in *all* observations.

9. The form of the further reduction will depend on the nature of the observation. Suppose, as a first case, that a star from the pole has been observed near the meridian,—

10. For each observation correct the chronometer time from chronometer error, which will give the true sidereal line of observation, and take the difference between the sidereal time and the star's R. A., which will give the star's hour angle. Reduce this to seconds. Suppose the number of seconds of time to be p,

11. Then compute for each observation the number

$$\left(\frac{225}{2}\sin. 1''\right) \times \frac{\text{cos. lat. . cos. star's declin}^{n}.}{\text{sin. star's Z D}} \times p^2,$$

and this is the correction in seconds of arc to the observed zenith distance to bring it to the meridian zenith distance,—always subtractive, except the star is below the pole.

12. This correction is to be applied to the circle reading; and it will be sometimes additive, sometimes subtractive, according as increasing readings of the circle in that position show increasing or decreasing zenith distances. For this purpose you must

* It is supposed here that when the observation on the star is made with the level to the observer's right hand, the increasing divisions read on the circle correspond to increasing zenith distances; if not, add equivalent for right hand level, and subtract that for left.

examine the construction of the circle. Thus the corrected circle readings for the meridian are found.

13. Half the difference of the two corrected circle readings in opposite positions of the instrument is the star's apparent zenith distance on the meridian. In using several pairs of observations, you may either compare the mean of all in one position with the mean of all in the other position, or follow any other rule usually adopted in similar cases. Half the sum of the corrected readings is the zenith point.

14. The refraction is to be computed and added to this approximate zen. dist., and it gives the star's true zenith distance.

15. Take out of the Nautical Almanac the star's declination for the day, considering it negative if the declination is of opposite name to that of the station. Add the true zenith distance, if the star is on the side of the zenith opposite to the pole, or add the true zenith distance to the star's declination, and subtract the sum from 180°, if the star is below the pole. Thus the latitude is obtained.

16. If the star is very far from the meridian, find the star's hour-angle (as in 10), and reduce it to arc. If this arc exceeds 90°, subtract it from 180°.

17. Find the star's distance from the meridian by the formula

$$\text{sin. dist. from meridian} = \text{cos. declin}^{n}. \times \text{sin. hour-angle.}$$

18. Find the star's distance above or below the pole by the formula

$$\text{tan. dist. above or below} = \text{cotan. declin}^{n}. \times \text{cos. hour-angle;}$$

(above, if the hour-angle is less than 90°.)

19. From the circle reading (7, 8) and the approx. zenith point (13) obtain an approximate zenith distance to *seconds*, and correct for refraction.

20. Then compute

$$\text{cos. star's referred zenith distance} = \frac{\text{cos. approx. zenith distance}}{\text{cos. star's dist. from meridian}},$$

and add to the referred zenith distance the distance above or below the pole (18) if the hour-angle is less than 90°, and subtract if greater than 90°. Thus the co-latitude is found.

21. Do the same from the observation with the instrument in the opposite position, using exactly the same approximate zenith point.

22. The mean of the two is a good co-latitude.

(IV.) *To determine the sidereal time in a place whose latitude is known, by observation with the altitude and azimuth instrument.*

1. Select a Nautical Almanac star which at the time is nearly east or west, and not very low.

2. Observe it with the instrument in the same manner as for latitude, noting the chronometer time of observation, position of face, readings of microscopes, and readings of level.

3. Reverse instrument in azimuth, and observe in like manner, noting the chronometer time. Repeat these observations if you think fit. Read barometer and thermometer.

4. Half the difference of the readings (fully reduced for miscroscopes and equivalent for levels) may be taken as the apparent zenith distance, corresponding to the mean of the times of observation.

5. Correct this apparent zenith distance for refraction, and you have the true zenith distance.

6. Take the star's declination from the Nautical Almanac, and subtract from 90°, if the declination is of the same name as the latitude, or add if of opposite name, which gives the polar distance: in like manner find co-latitude from latitude.

7. Add together true zenith distance, star's polar distance, and co-latitude, and call the sum S.

Formula, S — star's N P D, and S — co-latitude.

8. Then compute the hour-angle by the following formula:

2 log. sin. $\frac{1}{2}$-hour angle = log. sin. (S — star's N P D)
+ log. sin. (S — co-latitude) + 20 — log. sin. star's N P D)
— log. sin. co-latitude.

Convert the hour-angle into time.

9. If the star is west of the meridian, add this hour-angle to the star's R. A. (taken from the Nautical Almanac), and you have the true sidereal time. If the star is east, subtract the hour-angle from the star's R. A.

10. The difference of the mean of the two chronometer times from this sidereal time is the error of the chronometer.

(v.) *To determine the latitude and the sidereal time in a place where neither of them is known, by observations with the altitude and azimuth instrument.*

1. For this purpose two Nautical Almanac stars must be selected, and it is *indispensable* that *both* be *not* east or west: one may be nearly east or west; but the other must be nearly north or south. But as this choice might lead to a little trouble in the following computations, I recommend that in all cases two stars in positions pretty near to the directions intermediate to the cardinal points be taken,—thus:

One nearly N.E., and the other nearly S.E., or
,, S.E., ,, S.W., or
,, S.W., ,, N.W., or
,, N.W., ,, N.E.

It is indispensable that the azimuth be not nearly opposite, or the same; their difference ought to be as nearly as possible 90°.

2. Observe one star; note the time exactly; read the microscopes and level, and do the same as in IV. (2 and 3).

3. Observe the other star in exactly the same manner. Read barometer and thermometer.

4. Find the apparent zenith distance, and correct for refraction to obtain true zenith distance as in other cases.

5. From a map (or from any other means), estimate your latitude as well as you can, and then take two trial latitudes, one somewhat less and the other somewhat greater than the estimated latitude. As your uncertainty will never exceed a few minutes, it will probably suffice to take one trial latitude 5′ greater and one 5′ less than the estimate.

6. With each trial latitude, determine the chronometer error (IV., 10) by each of the stars, going through the operation of No. IV. four times.

7. The true latitude will be that which makes its two chronometer errors equal. Probably neither of the trial latitudes will do this. But observing how much the discordance alters between them, you will have no difficulty in finding the true latitude which will remove the discordance. Thus—suppose latitude 45° 15′ made the chronometer error by star A. $46^s{\cdot}2$, and by star B. $50^s{\cdot}2$ (discordant 4 seconds); and

suppose latitude 45° 25′ made the error by A. $53^s{\cdot}4$, and by B. $37^s{\cdot}4$ (discordant 16^s the opposite way); then 10′ of latitude has changed the discordance 20^s, and therefore 2′ of latitude will remove the first discordance of 4^s, and the latitude is 45° 17′; and since 10′ altered the error by A. $7^s{\cdot}2$, and by B. $12^s{\cdot}8$, 2′ will alter the former by $1^s{\cdot}44$, and the latter by $2^s{\cdot}56$; and both agree in giving the error $47^s{\cdot}64$.

(VI.) *Observations of equal altitude not recommended for use.*

1. If the object of these observations is simply to obtain the correction of the chronometer, the observations should be taken as near as possible to the prime vertical, east or west.

2. For a star, the instrument, whatever it is, should be set to a known reading, and the time should be noted when the star reaches that reading in the east; again the star should be noted when it reaches the same reading in the west. The mean of these two times is the same when the star passes the meridian.

3. It will be best not to keep the instrument fixed, but to set it successively to a number of different readings on the east side, and to set it again to the same readings in the opposite direction. Thus a number of different results will be obtained, and the risk of loss will be diminished.

4. For the sun, the same limb (upper or lower) should be observed; but there is an additional correction necessary for the change of the sun's declination, or N. P. D. If the N. P. D. is *increasing*, the sun reaches the same Z. D. on the west side *too soon*, and therefore the time for the west side must be increased. The calculations will be thus: the increase of the sun's N. P. D. will be calculated (the interval of time being nearly known) from the Nautical Almanac: the latitude of the station is supposed to be nearly known, and the approximate hour angle at either observation (half the interval of time converted into arc) is nearly known. Then the correction to western time in seconds of time is—

$$\frac{\text{tan. latitude}}{15\,.\,\text{sin. hour-angle}} \times \text{increase N P D} - \frac{\text{tan. declin}^{n}.}{15\,.\,\text{tan. hour} <} \times \text{increase N P D};$$

the increase of N. P. D. being taken as seconds of arc.

Then the means are to be taken as for a star.

5. If the object is to obtain latitude as well as chronometer correction, the two sets of observations should be made when the star or sun is nearly S. E. or S. W. The method of making the observations, and applying corrections to the time, and thence deducing the time of transit, is the same as before.

6. Then the accurate hour-angle for the first observation (the difference between the time of observation and the time of transit) being found, and the absolute zenith distance being taken and corrected for refraction, and in the instance of the sun for parallax and semi-diameter, and the star's or sun's N. P. D. being taken accurately from the Nautical Almanac, the latitude will be found by the following process:

$$\left.\begin{matrix}\text{Tan. star's referred}\\ \text{dist. from pole}\end{matrix}\right\} = \text{tan. N P D} \times \text{cos. hour-angle.}$$

$$\text{Sin. star's azimuth} = \frac{\text{sin. hour} < \times \text{sin. N P D}}{\text{sin. zenith distance}}.$$

$$\left.\begin{matrix}\text{Tan. star's referred}\\ \text{dist. from zenith}\end{matrix}\right\} = \text{tan. zenith dist.} \times \text{cos. azimuth.}$$

Co-lat. = star's referred distance from pole − star's referred distance from zenith.

(VII.) *General remarks on the rise of the sun instead of a star, in any of the preceding observations.*

1. The sun may be substituted for a star in any of the various classes of observations already mentioned. But its use is always more troublesome, and it comes, for many of them, but once a day; and for some it is useless, if it can be caught but once in a hasty sight. It is recommended, therefore, that the principal, if not the only, reliance be placed on observations of stars.

2. In using the sun, the time by account must always be reduced to Greenwich mean time, and with this the sun's place must be computed from the Nautical Almanac. Thus, in longitude 67° 50′ west (by account), suppose that the sun was observed on May the 24th, about three in the afternoon (by the reputed time at the place); then as the sun passes Greenwich before he passes this western place, the time will be later at Greenwich by the time corresponding to 67° 50′ of arc, or 4 h. 31 m. 20 s.: therefore the time at Greenwich will be, May 24th, 7 h. 31 m. nearly. and with this time the sun's R. A. and N. P. D. must be computed, by interpolation, among the places given in the Nautical Almanac for Greenwich mean noon.

3. The change of the sun's N. P. D. must, in many instances, be taken into account. Thus, if the sun were observed as in No. II., the change of N. P. D. between the first observation and the second must be computed, and it must be considered that if the N. P. D. is increasing, the second observation occurs too late, and must be corrected by the quantities

$$\frac{1}{15.\ \sin.\ \mathrm{NPD} \times \cos.\ \mathrm{NPD}.\ \tan.\ \text{hour-angle}} \times \text{change of NPD};$$

the change of N. P. D. being expressed in seconds of arc, and the correction to time being expressed in seconds of time. Then, in further operations, the N. P. D. for the first observation must be used.

A similar result of change of N. P. D. is given in No. VI.

4. In all cases where the sun's altitude or zenith distance is measured, parallax must be applied subtractively from observed zenith distances.

Its formula is $8''{\cdot}7 \times$ sin. zenith distance. It is to be used in Nos. III. IV. V.

5. In all cases observations must be made of the sun's limb, and not of his centre, which cannot be fixed on with accuracy. If possible, therefore, observations should be so managed that the observations of the two limbs should prevent the necessity for applying any correction for semi-diameter. Thus, in transits the first and second limb should be observed. In altitudes (whether for latitude or time), the upper and lower limb should be observed. If from clouds, &c., this cannot be done,—for transits, the duration of transit of semi-diameter, from the Nautical Almanac, must be applied. For altitudes, the semidiameter, taken from the Nautical Almanac, must be applied, after application of refraction and parallax. Observations on the stars are free from all these troubles. (Signed) G. B. AIREY.

PART III.—OBSERVATORY, PORTABLE.*

According to the nature and size of the instrument to be protected, Portable Observatories are made either of wood, or partly of wood and partly of canvas, strengthened with iron ties and iron angle-bars, and secured in position by guy-ropes,

* By Colonel Robinson, R.E.

pickets, &c. On the Ordnance Survey of Great Britain, four kinds or classes are used for the various sized theodolites which are employed on the triangulation.

Plates VIII. and IX. Fig. No. 1 is for the largest class of theodolite used, viz. the three feet. Its form is hexagonal, and it consists of the following pieces :

1. Six panels of wood, each 5 feet 6 inches long by 4 feet 6 inches high, framed of 1-inch deal with ½-inch boarding. (See fig. 4.)

The top style carries two pieces of flat iron, with eyes to receive corner iron bars : one of the under cross-bars also carries two eyes, to receive the lower angle-bars.

2. Six corner-posts of deal (fig. 5), to support the roof, each 4 feet 6 inches high, 3 inches in diameter.

The top has a hole sunk in it, 3 inches in depth, to receive the upright angle-bar, and is bound round with iron plate to strengthen it at this part.

3. Six iron corner bars (fig. 6), made double in the centre, with an opening 3 inches wide. The lower end goes into the top of the corner post ; the upper end receives the wall-plates, rafter, and rose for guy-rope : they are made of rod iron, 1 inch in diameter. They revolve, and admit of objects being observed through them.

Plate IX. 4. Six wall-plates of deal, 5 feet 6 inches long, 2 inches wide by 2 inches deep. (Fig. 3.) These are notched, and bound with sheet iron at the ends, and have a hole bored through, to fit upon the iron angle-bars.

5. Six rafters, 7 feet long, 2½ inches wide by two inches deep : the lower end bevelled, and shod with sheet iron, and bored, to go upon the angle-bar. These are all fastened with butt-hinges to one central piece of wood of 1 foot in diameter by two inches thick : when taken down, the rafters close together, and are carried in a long canvas bag.

6. One iron bolt (fig. 3), 12 inches long, 1¼ inch diameter, passes through this central block ; it has a screw and nut on the under side, and a shoulder on the outside : it is to receive the large rose which carries the long guy-ropes.

Plate VIII. 7. Six iron bars (fig. 1), 4 feet long, 1 inch diameter, and six of 3 feet long, 1 inch diameter, to bind the panels together at the angles. The upright posts are secured in their places and to the panels by twelve iron angle-pieces and twelve iron shackles

Plate IX. (figs. 7 and 8). The former are of ⅜-inch flat iron, bent to an angle of 120°, with projecting pieces passing through the panels, having holes to receive the ends of the shackles.

The roof is covered with a very strong description of sail canvas, of double thickness : the seams are strengthened with girth webbing. It is made in one piece, and is put on from the outside, sliding down over the rafters, and has eyelet-holes, to receive the projecting ends of the iron angle-bars.

Attached to this roof are curtains made of the same canvas (but only once thick), of two feet in depth, which cover the openings between the top of the panels and the wall-plates. The lower ends button over iron staples provided in the panels, and are secured by cords passing through them.

The curtains are rolled up when required, and tied to the wall-plates. Each panel has a piece of painted canvas, fixed at one side, of about 7 or 8 inches wide, which buttons over the angle upon a row of iron staples in the next panel.

Two panels, each provided with a small door, 1 ft. 8 in. wide by 2 ft. 8 in. deep, are usually placed north and south.

For the purpose of observing the Pole star, by which the direction of the meridian is obtained, a piece is cut out of the canvas roof, on the north side, leaving an opening

Plate VIII. of 3 feet long by 1 foot wide (fig. 2). To cover this, when not required for observing, this side has an extra thickness or flap of canvas, which is sewn at one side, and

buttons over a row of iron staples, fastened to the canvas of the opposite angle, and secured by a bit of cord run through them.

A large wooden rose fits upon the iron bar projecting through the roof at top, and six long guy-ropes, of about 100 feet each in length, are attached to it, to be secured to pickets in the ground. A smaller rose fits upon each projecting end of the angle-bars, and has a small guy-rope attached to it.

For use, the observatory inside is generally floored with joists and boards, leaving in the centre a well for the pedestal or frame-work supporting the instrument, care being taken that the latter is perfectly insulated, so as to be free from shake or jar, from persons walking on the floor.

This kind of observatory is used upon the highest mountains and in the most exposed places. It is generally the practice, however, to build round it on the outside, and just touching it, a wall of loose stones, about half-up the panels. With this precaution, it was never known (for years) to yield or give way in the least, although, at times, everything else in the camp would be blown over and levelled with the ground.

Plate IX. figs. 3, 4, 5, 6, 7, 8.

No. 2.—This class of observatory is used for the second class of theodolites, such as the 18-inch. It is precisely similar in its construction to the former, but is a size smaller, each panel being made about 4 feet 9 inches in length by 4 feet in height. The dimensions of the other parts are lessened to correspond with the panels. This observatory is also very strong, and may be used in the most exposed situations.

Plate X.

No. 3.—This is used in the District Surveys for the 12-inch or 10-inch theodolites: The shape, like the former ones, is hexagonal. It consists of a canvas roof, with side curtains, also of canvas, reaching to the ground, supported upon a skeleton frame-work, consisting of

Six upright poles, 5 feet 9 inches long, $2\frac{1}{4}$ inches diameter, with projecting iron pins, 8 inches long, at the upper end, to receive the wall-plates and rafters: the tops are bound with a piece of sheet iron.

Six wall-plates, each 4 feet long, $1\frac{3}{4}$ inch by $1\frac{3}{4}$ inch, with holes at the ends, to pass over the pins upon the top of the upright poles.

Six rafters, 5 feet 3 inches long, 2 inches by $1\frac{3}{4}$ inch, all permanently fastened by butt-hinges to a central piece of wood, 8 inches in diameter and 2 inches thick.

An iron bolt, with moveable nut underneath, passes through this, to receive the rose on the top.

The canvas roof goes over the frame-work, and is made in one piece, with flaps 8 inches deep.

The canvas walls are made separate from the roof, in one or two pieces, and are fastened to it with hooks and eyes. For use, they are unhooked, and drawn on one side.

Plate XI. fig. 11.

No. 4 is used in the District Surveys for the smaller theodolites, 7-inch, &c.

A triangular frame of wood, each side 3 feet in length, is supported upon three poles or legs, each 7 feet 4 inches long: the canvas covering consists of two pieces; 1st, The head, which covers the triangle at the top, and extends about two feet down the sides of the poles: it is made of strong duck canvas. 2ndly, The walls are made of a piece of duck canvas, 15 feet 6 inches long at the bottom, 9 feet 6 inches at the top, and 5 feet 4 inches wide.

This covers in two sides of the triangle only, but it can be shifted to any two required for shelter from the wind. The canvas walls button over iron staples in the poles supporting the head. The side walls to the latter can be raised when required, by a piece of wood notched at the foot and resting upon the corner guy-rope. The

upright poles have an iron pin at the foot, 3 inches long, and at the top there is an iron prong, or fork of flat iron, by which they are secured to the top pieces by nuts and screws.

The Portable Observatory for the zenith sector, shown in Plates XII. and XIII., is a wooden building formed of panels and uprights, which can be strongly bound together: the side panels are fitted into rabbets cut in the frame, and secured on the inside with bent iron plates and screws. It is 10 feet square in plan at the bottom, and 8 feet 10 inches square at the top; ten feet in height to spring of roof; rise of roof, 2 feet.

The four corner posts are of 5″ × 5″ scantling,—the four bottom plates are of 6″ × 5″ ditto,—bolted and nutted to the corner post as in a bedstead;—the four top plates are of 5″ × 5″ scantling, notched and pinned to the corner posts.

The frame is strengthened mid-way by four additional horizontal pieces.

Each side has three upright pieces, 3″ + 3″, mortised and tenoned into the plates.

There are eight panels to each side, of $\frac{1}{2}$-inch boarding.

On the north and south sides one of the panels is hung as a door, and contains a small glass window.

The roof has an opening in the centre of 5 feet 4 inches long, by 1 foot 4 inches wide, fitted with two small trap-doors, which are opened or shut from the inside by means of a cord passing through a fixed pulley at the end of an iron rod, as shown in the section, and carried through another fixed pulley in one of the side posts.

The roof is formed of six panels which slide in grooves in the sides of the hip and central rafters.

The corner posts and wall-plates have iron staples driven into them.

The whole building is covered with duck canvas, which buttons over these staples and cords run through them keep all secure.

The floor is formed of joists and boards, leaving room for the pedestal or frame-work support for the instrument in the centre.

This observatory may be used in the most exposed situations.

Plate XIV. shows a Portable Observatory which was made for a Transit instrument, and used at Valentia, in Ireland. It is a wooden building, strongly framed together. The sides and ends are formed of panels fitted into rabbets cut in the scantling of the frame-work, and secured to them on the inside with bent iron plates and screws.

In plan, the building is 10 feet 9 inches by 8 feet 5 inches; the height is 7 feet 10 inches to spring of roof; rise of the latter, 4 feet.

There are two tie-beams, king-posts, and rafters in the centre, leaving between them an opening of 1 foot 1 inch in the clear on the sides of the roof. This opening is continued to the ground-plate on each side.

Doors are fitted to these openings, which can be raised or shut at pleasure from the inside. The door in the roof is raised by means of a cord attached to one end of a small iron lever, turning on a pivot, secured to one of the rafters, and having a small roller wheel at the other end.

The roof is formed of eight angular panels, which slide in grooves cut in the sides of the rafters.

Iron staples are fixed in the corner posts and wall-plates, over which a covering of canvas duck is buttoned and secured by cords passing through them.

Stars near the zenith are observed by turning the double iron bar which forms the ridge of the roof between the two king-posts.

A similar bar is provided in the top wall-plates, which might otherwise interfere with the observations.

The Officers employed on the Boundary Survey in North America, under the Treaty of Washington, used tents for observatories, made of duck canvas only, supported upon a ridge-pole 10 feet long, with two upright poles of 10 feet each.

In plan, the tent enclosed a space of 10 feet square.

The north and south sides had canvas walls, 5 feet high.

In the slope of the roof, on each side, a portion of the canvas was made to turn back, leaving an opening, when required for observing, of about 1 foot 6 inches wide.

When the ridge-pole interfered with a star passing near the zenith, it was lowered a little by slackening the guy-ropes.

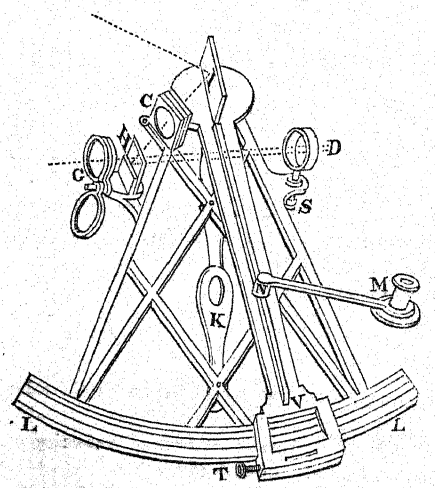
These were for the protection of the transit instruments. The altitude and azimuth instruments were used always in the open air, without any observatory. W. R.

PART IV.—DESCRIPTION OF THE PRINCIPAL ASTRONOMICAL INSTRUMENTS.*

1. Hadley's Sextant; 2. Troughton's Reflecting Circle; 3. The Transit Instrument; 4. Altitude and Azimuth Instruments; with brief remarks upon other instruments used for astronomical purposes.

Hadley's Sextant.—This instrument differs from the pocket sextant in its appearance, from the absence of the box in which the pocket sextant is fixed, and in its size, varying usually from 4 inches to 6 inches radius, and in its requiring and admitting of more perfect and minute adjustment.

L L is the graduated limb of the instrument, graduated from 0° to 140° at every 10′ or 20′, according to its size, and subdivided by the vernier V, to 10″ or 20″, thus enabling us to read off angles by estimation, to 5″. The limb is also graduated through a small space, called the arc of excess, on the other side of the zero point. T is the tangent screw, for giving a slow motion to the index bar, after it has been clamped by a screw at the back of the instrument, not shown in the figure. M is a microscope, attached to the index bar by an arm moveable round the centre N, so as to command a view of the vernier throughout its entire length. I is the index glass, or first reflector, attached to and moving with the index bar; and H is the horizon glass, having its lower half silvered to form the second reflector, and its upper half transparent. Four dark glasses are placed at C, any



* By J. F. Heather, M.A., late of the Royal Military Academy, Woolwich.

one or more of which can be turned down between the index glass and horizon glass to moderate the intensity of the light from any very bright object viewed by reflection ; and at G are three dark glasses, any one or more of which can be turned up to moderate the intensity of the light from any bright object viewed directly through the transparent part of the horizon glass. D is a ring for carrying the telescope, attached to a stem S, called the up-and-down piece, which can be raised or lowered by means of a milled-headed screw. The use of this up-and-down piece is to raise or lower the telescope, till the objects seen directly and by reflection appear of the same brightness. K is the handle by which the instrument is held.

In selecting an instrument, care must be taken that all the joints of the frame are close, without the least opening or looseness, and that all the screws act well, and remain steady, while the instrument is shaken by being carried from place to place. All the divisions on the limb and vernier, when viewed through the microscope, must appear exceedingly fine and distinct, and the inlaid plates, upon which the divisions are marked, must be perfectly level with the surface of the instrument. The index, or zero, of the vernier, should also be brought into exact coincidence successively with each division of the limb, till the last division upon the vernier reaches the last division upon the limb ; and if the last division of the vernier do not in each case also exactly coincide with a division upon the limb, the instrument is badly graduated, and must be rejected. All the glass used in the instrument should be of the best quality, and the glasses of the reflectors should each have their faces ground and polished perfectly parallel to each other, to avoid refraction. Look, therefore, into each reflector, separately, in a very oblique direction, and observe the image of some distant object ; and if the image appears clear and distinct in every part of the reflector, the glass is of good quality ; but if the image appears notched, or drawn with small lines, the glass is veiny, and must be rejected. Again, if the image appears singly, and well defined about the edges, the two surfaces of the glass are truly parallel ; but if the edge of the image appears misty, or separated like two images, the two surfaces are inclined to one another. The examination will be more perfect if the image be examined with a small telescope.

A plain tube and two telescopes, one showing objects inverted, and the other erect, are usually supplied with the sextant. A dark glass is also supplied to fit on to the eye-end of the telescope, and a key for turning the adjusting screws.

To examine the error arising from the imperfection of the dark glasses.—Fit the dark glass to the eye-end of the telescope, and, all the shades being removed, bring the reflected image of the sun into contact with his image seen directly through the unsilvered part of the horizon glass. Then remove the dark glass from the eye-end of the telescope, and, setting up first each shade separately, and then their various combinations, if the two images do not in any case remain in contact, the angle through which the index must be moved to restore the contact is the error of the dark glass, or combination of dark glasses, used in the observation, and which error should be recorded for each glass, and each combination of the glasses.

The adjustments of the instrument consist in setting the horizon glass perpendicular to the plane of the instrument, and in setting the line of collimation of the telescope parallel to the plane of the instrument.

To adjust the horizon glass.—While looking steadily at any convenient object, sweep the index slowly along the limb, and if the reflected image do not pass exactly over the direct image, but one projects laterally beyond the other, then the reflectors are not both perpendicular to the face of the limb. Now the index glass is fixed in its place by the maker, and generally remains perpendicular to the plane of the instru-

ment, and if it be correctly so, the horizon glass is adjusted by turning a small screw at the bottom of the frame in which it is set, till the reflected image passes exactly over the direct image.

To examine if the index glass be perpendicular to the plane of the instrument.—Bring the vernier to indicate about 45°, and look obliquely into this mirror, so as to view the sharp edge of the limb of the instrument by direct vision to the right hand, and by reflection to the left. If, then, the edge and its image appear as one continued arc of a circle, the index glass is correctly perpendicular to the plane of the instrument; but if the arc appears broken, the instrument must be sent to the maker to have the index glass adjusted.

To adjust the line of collimation.—1. Fix the telescope in its place and turn the eye-tube round, that the wires in the focus of the eye-glass may be parallel to the plane of the instrument. 2. Move the index till two objects, as the sun and moon, or the moon and a star, more than 90° distant from each other, are brought into contact at the wire of the diaphragm which is nearest the plane of the instrument. 3. Now fix the index, and altering slightly the position of the instrument, bring the objects to appear on the other wire; and if the contact still remain perfect, the line of collimation is in correct adjustment. If, however, the two objects appear to separate at the wire that is further from the plane of the instrument, the object-end of the telescope inclines towards the plane of the instrument; but, if they overlap, then the object-end of the telescope declines from the plane of the instrument. In either case the correct adjustment is to be obtained by means of the two screws which fasten to the up-and-down piece the collar holding the telescope, tightening one screw and turning back the other, till, after a few trials, the contact remains perfect at both wires.

The instrument having been found by the preceding methods to be in perfect adjustment, set the index to zero, and if the direct and reflected images of any object do not perfectly coincide, the arc, through which the index has to be moved to bring them into perfect coincidence, constitutes what is called the index error, which must be applied to all observed angles as a constant correction.

To determine the index error.—The most approved method is to measure the sun's diameter, both on the arc of the instrument, properly so called, to the left of the zero of the limb, and on the arc of excess to the right of the zero of the limb. For this purpose, firstly, clamp the index at about 30′ to the left of zero, and, looking at the sun, bring the reflected image of his upper limb into contact with the direct image of his lower limb, by turning the tangent screw, and set down the minutes and seconds denoted by the vernier: secondly, clamp the index at about 30′ to the right of zero, on the arc of excess, and, looking at the sun, bring the reflected image of his lower limb into contact with the direct image of his upper limb, by turning the tangent screw, and set down the minutes and seconds denoted by the vernier underneath the reading before set down. Then half the sum of these two readings will be the correct diameter of the sun, and *half their difference will be the index error.* When the reading on the arc of excess is the greater of the two, the index error, thus found, must be added to all the readings of the instrument; and when the reading on the arc of excess is the less, the index error must be subtracted in all cases. To obtain the index error with the greatest accuracy, it is best to repeat the above operation several times, obtaining several readings on the arc of the instrument, and the same number on the arc of excess; and the difference of the sums of the readings in the two cases, divided by the whole number of readings, will be the index error; while the sum of all the readings, divided by their number, will be the sun's diameter.

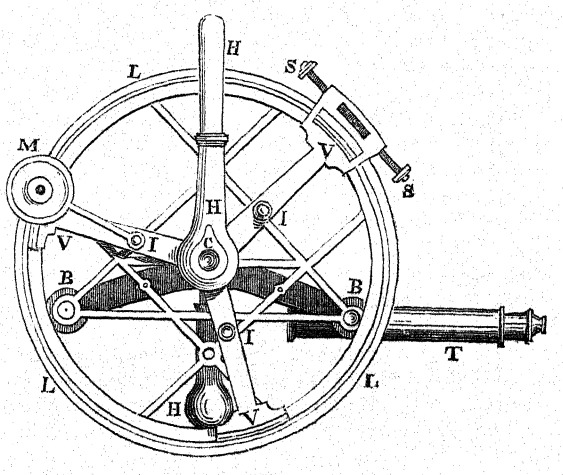
EXAMPLE.

Readings on the Arc of Instrument.			Readings on the Arc of Excess.		
	′	″		′	″
	35			29	25
	35	5		29	35
	35	10		29	20
	105	15		88	20
	88	20		105	15
No of readings 6)	16	55	difference.	6) 193	35 sum.
	2	49	index error.	32	15·8 sun's diameter.

The readings on the arc of excess being less than those on the arc of the instrument, the index error, 2′ 49″, is to be subtracted from all the readings of the instrument.

Note.—In taking off the readings on the arc of excess, the vernier must be read backwards; that is, the division read off on the limb, being the division next to the left of the zero of the vernier, the divisions of the vernier to be added must be reckoned from the other end of the vernier to the division coinciding with a division upon the limb; or the reading of the vernier forwards, according to the usual method, may be subtracted from 10′, the limb being divided to 10′, and the remainder added to the reading of the division upon the limb next to the left of the zero of the vernier, as before.

Troughton's Reflecting Circle.—In this instrument, which is the same in principle as the sextant, the limb is a complete circle, L L L. It has three verniers, V V V, one of which is furnished with the clamp and tangent screw, S S, for regulating the contacts; and the verniers are read by a magnifier, M, which may be applied successively to all the verniers. In the middle of the frame, and attached to it by a broad base or flanch, is a hollow centre, upwards of 2 inches long, in which an axis revolves. The triple vernier bar, I I I, is attached at one end of the axis, and the index glass at the other, so that both turn together, but on opposite sides of the instrument. A secondary frame, B B, carries the telescope T, the horizon glass, and the dark glasses. H H are two handles, one of them bent, and passing round to the



centre of the instrument on the other side; and there is a third handle, which can be screwed on perpendicular to the plane of the instrument, either into the handle at C, or upon the other side of the instrument, at its centre. The adjustments and manner of observing with the instrument are explained by the inventor, Mr. Troughton, as follows:

Directions for observing with Troughton's reflecting circle.—"Prepare the instrument for observation by screwing the telescope into its place, adjusting the drawer to focus, and the wires parallel to the plane, exactly as you do with a sextant; also set the index forwards to the rough distance of the sun and moon, or moon and star; and, holding the circle by the short handle, direct the telescope to the fainter object, and make the contact in the usual way. Now read off the degree, minute, and second, by that branch of the index to which the tangent screw is attached; also, the minute and second shown by the other two branches: these give the distance taken on three different sextants; but as yet, it is only to be considered as half an observation: what remains to be done, is to complete the whole circle, by measuring that angle on the other three sextants. Therefore set the index backwards nearly to the same distance, and reverse the plane of the instrument, by holding it by the opposite handle, and make the contact as above, and read off as before what is shown on the three several branches of the index. The mean of all six is the true apparent distance, corresponding to the mean of the two times at which the observations were made.

"When the objects are seen very distinctly, so that no doubt whatever remains about the contact in both sights being perfect, the above may safely be relied on as a complete set; but if, from the haziness of the air, too much motion, or any other causes, the observations have been rendered doubtful, it will be advisable to make more: and if, at such times, so many readings should be deemed troublesome, six observations, and six readings, may be conducted in the manner following:—Take three successive sights forwards, exactly as is done with a sextant; only take care to read them off on different branches of the index. Also make three observations backwards, using the same caution: a mean of these will be the distance required. When the number of sights taken forwards and backwards are unequal, a mean between the means of those taken backwards and those taken forwards will be the true angle.

"It need hardly be mentioned, that the shades, or dark glasses, apply like those of a sextant, for making the object nearly of the same brightness; but it must be insisted on, that the telescope should, on every occasion, be raised or lowered, by its proper screw, for making them perfectly so."

The foregoing instructions for taking distances apply equally for taking altitudes by the sea or artificial horizon, they being no more than distances taken in a vertical plane. Meridian altitudes cannot, however, be taken both backwards and forwards the same day, because there is not time; all, therefore, that can be done is, to observe the altitude one way, and use the index error; but, even here, you have a mean of that altitude, and this error taken on three different sextants. Both at sea and land, where the observer is stationary, the meridian altitude should be observed forwards one day, and backwards the next, and so on alternately from day to day: the mean of latitudes, deduced severally from such observations, will be the true latitude; but in these there should be no application of index error, for that being constant, the result would in some measure be vitiated thereby.

"When both the reflected and direct images require to be darkened, as is the case when the sun's diameter is measured, and when his altitude is taken with an artificial horizon, the attached dark glasses ought not to be used: instead of them, those which apply to the eye-end of the telescope will answer much better; the former having

their errors magnified by the power of the telescope, will, in proportion to this power, and those errors, be less distinct than the latter.

"In taking distances, when the position does not vary from the vertical above thirty or forty degrees, the handles which are attached to the circle are generally most conveniently used; but in those which incline more to the horizontal, that handle which screws into a cock on one side, and into the crooked handle on the other, will be found more applicable.

"When the crooked handle happens to be in the way of reading one of the branches of the index, it must be removed, for the time, by taking out the finger screw which fastens it to the body of the circle.

"If it should happen that two of the readings agree with each other very well, and the third differs from them, the discordant one must not on any account be omitted, but a fair mean must always be taken.

"It should be stated, that when the angle is about thirty degrees, neither the distance of the sun and moon, nor an altitude of the sun, with the sea horizon, can be taken backwards; because the dark glasses at that angle prevent the reflected rays of light from falling on the index glass: whence it becomes necessary, when the angle to be taken is quite unknown, to observe forwards first, where the whole range is without interruption; whereas in that backwards you will lose sight of the reflected image about that angle. But in such distances, where the sun is out of the question, and when his altitude is taken with an artificial horizon, (the shade being applied to the end of the telescope,) that angle may be measured nearly as well as any other; for the rays incident on the index glass will pass through the transparent half of the horizon glass without much diminution of their brightness.

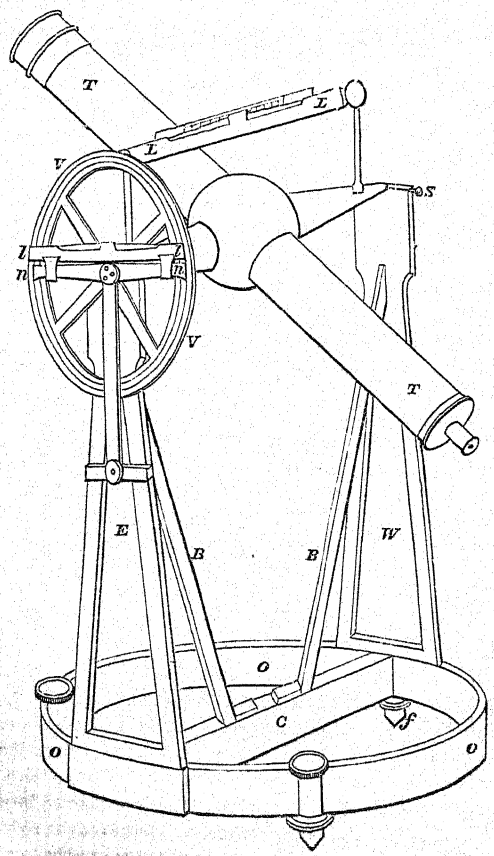
"The advantages of this instrument, when compared with the sextant, are chiefly these: the observations for finding the index error are rendered useless, all knowledge of that being put out of the question by observing both forwards and backwards. By the same means the errors of the dark glasses are also corrected; for if they increase the angle one way, they must diminish it the other way by the same quantity. This also perfectly corrects the errors of the horizon glass, and those of the index glass very nearly. But what is of still more consequence, the error of the centre is perfectly corrected by reading the three branches of the index; while this property, combined with that of observing both ways, probably reduces the errors of dividing the one-sixth part of their simple value. Moreover, angles may be measured as far as one hundred and fifty degrees, consequently the sun's double altitude may be observed when his distance from the zenith is not less than fifteen degrees, at which altitude the head of the observer begins to intercept the rays of light incident on the artificial horizon; and, of course, if a greater angle could be measured, it would be of no use in this respect.

"This instrument, in common with the sextant, requires three adjustments: first, the index glass perpendicular to the plane of the circle. This being done by the maker, and not liable to alter, has no direct means applied to the purpose: it is known to be right when, by looking into the index glass, you see that part of the limb which is next you, reflected in contact with the opposite side of the limb as one continued arc of a circle: on the contrary, when the arc appears broken where the reflected and direct parts of the limb meet, it is a proof that it wants to be rectified. The second is, to make the horizontal glass perpendicular. This is performed by a capstan screw, at the lower end of the frame of that glass; and is known to be right when by a sweep of the index the reflected image of any object will pass exactly over, or cover the image of that object seen directly. The third adjustment is, for making the line of collimation parallel to the plane of the circle. This is performed by two

small screws, which also fasten the collar into which the telescope screws to the upright stem on which it is mounted: this is known to be right when, the sun and moon, having a distance of one hundred and thirty degrees or more, their limbs are brought in contact, just at the outside of that wire which is next to the circle, and then on examination are found to be just the same at the outside of the other wire: their being so is the proof of adjustment."

Another instrument of Troughton's construction, upon the principle of the sextant, is the *Dip Sector*, for measuring the dip of the horizon. Any person who is thoroughly acquainted with the sextant will find no difficulty in using it, after a few words of explanation from the maker.

The Transit Instrument.—The reflecting nstruments, which we have just described, from their portability and the promptitude and facility with which they may be used in all situations, and upon all occasions, are most useful instruments to the surveyor. The sextant or reflecting circle, with an artificial horizon, and a good chronometer, forms, in fact, a complete observatory, with which the latitudes and longitudes of places may be determined to a great degree of accuracy; while to the navigator a reflecting instrument is indispensable; all other instruments requiring to be supported upon a stand perfectly at rest, while the sextant and similar instruments are held in the hand, and perform their duty well on the deck of a rolling ship. In permanent observations, however, the capital angular instruments are placed permanently in the plane of the meridian, and the measurements sought for by their aid are the exact times at which the observed objects pass the meridian, and their angular altitudes or zenith distances when upon the meridian. The instrument with which the first of these measurements is obtained is called a *transit instrument*, *transit telescope*, or merely a *transit*. Transits of portable dimensions, besides their use in small or temporary observatories, are also found serviceable to the surveyor, for determining, with the greatest possible accuracy, the true north point, and thence



setting out a line in any required direction; and to the scientific traveller, for determining the longitude of any place from astronomical observations, and for adjusting his time-keepers with greater accuracy than can be obtained by his sextant or reflecting circle. The annexed figure represents a portable transit.

TT is a telescope formed of two parts, connected by a spherical centre-piece, into which are fitted the larger ends of two cones, the common axis of which is placed at right angles to the axis of the telescope, to serve as the horizontal axis of the instrument. The two small ends of these cones are ground into two perfectly equal cylinders, called *pivots*. The pivots rest upon angular bearings or ʏ's. The ʏ's are supported upon the standards E and W. of which E may be called the eastern, and W the western standard: and one of the ʏ's is fixed in a horizontal groove, on the western standard, so that, by means of the screw S, one end of the axis may be pushed a little forwards or backwards, and a small motion in azimuth be thus communicated to the telescope.* The standards, E and W, are fixed by screws upon a brass circle, O O O, and steadied by oblique braces, B B, which spring from the cross-piece C.

On one end of the axis is fixed, so as to revolve with the axis, a vertical circle, V V; and a double index bar, furnished with a spirit-level, *l l*, to set it horizontal, carries two verniers, *n n*, adapted to the vertical circle, and showing the angle of elevation of the telescope. The index bar is fixed in its position by a clamping screw, and can be fixed upon either the eastern or western standard, at pleasure, while the telescope, with its attached circle, can also be lifted out of, and have its position reversed in the ʏ's. The pivot, which does not carry the vertical circle, is pierced, and allows the light from a lamp to fall upon a plane speculum, fixed, in the spherical centre piece, on the axis of the telescope, and inclined to this axis at an angle of 45°. The light is thus thrown directly down the telescope, and illuminates the wires of the diaphragm, placed in the principal focus of the telescope. Of these wires one is horizontal; and a vertical wire intersecting it in the centre of the field of view, gives by its intersection with it, the collimating point. There are, then, other vertical wires arranged in pairs equidistant from the central vertical wires, so that we have either three or five, or seven vertical wires, the most common number being five. The lamp has a contrivance for regulating the quantity of light thrown into the telescope, by turning a screw, so that the light from a small star may not be overpowered by the superior light of the lamp.

The requisites of a good instrument are—1stly, that the telescope be of the best quality, and properly tested; 2ndly, that the feet-screws act well and remain steady; 3rdly, that all the screws, by which the instrument is put together, are turned home, and remain so, after the instrument has been shaken by carriage; 4thly, that the length of the axis be just sufficient to reach from one ʏ to the other, without either friction or liberty; 5thly, that the lamp be held so as not to require adjustment for position; 6thly, that the screws of adjustment of the diaphragm, and ʏ's, be competent to give security of position to the parts adjusted by them; 7thly, that the metallic parts be free from flaws in casting, and that the pivots be formed of hard bell-metal, and incapable of rusting.

The principal adjustments of the transit are three:

1st. To make the axis on which the telescope moves horizontal.

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* The large transits in permanent observations have their ʏ's placed in two dove-tailed grooves, one horizontal, and the other vertical. By means of the latter, one end of the axis may be raised or depressed: but in the portable transit the same object is attained by turning one of the foot-screws upon which the entire instrument rests.

2nd. To make the line of collimation move in a great vertical circle, by setting it perpendicular to the horizontal axis.

3rd. To make it move in that vertical circle, which is the meridian.

To make the axis horizontal.—Apply to the pivots the large level, L L, which is supplied with the instrument for this purpose, and is either constructed to stand upon the pivots, in which case it is called a striding level, or suspended from the pivots, and is called a hanging level. Bring the air-bubble to the centre of its run, by turning the foot-screw *f*. Turn the level end for end, and if the air-bubble retains its position, the axis is horizontal; but if not it must be brought back half by the foot-screw *f*, and the other half by turning the small screw at one end of the level. Repeat the operation till the bubble retains the same position in both positions of the level, and the axis will be horizontal.

To adjust the line of collimation in azimuth.—Direct the telescope to some distant, small, and well-defined object, and bisect it by one extremity of the middle vertical wire, giving the telescope the azimuthal motion necessary for this purpose by turning the screw S. By elevating or depressing the telescope, examine whether the object is bisected by every part of the middle vertical wire; and, if not, loosen the screws which hold the eye-end of the telescope in its place, and turn the end round very carefully till the error is removed. Lift the transit off the Y's, and reverse it, so that the end of the axis, which was upon the eastern Y, may now be upon the western, and *vice versâ*; and, if the object is still bisected by the central vertical wire, the collimation in azimuth is perfect; but, if not, move the centre of the cross wires half-way towards the object by turning the small screws which hold the diaphragm, and if this half-distance has been correctly estimated, the adjustment will be accomplished. Again, bisect the object by the centre of the cross wires by turning the azimuthal screw S, and repeat the operation till the object is bisected by the centre of the cross wires in both positions of the instrument, and the adjustment will be known to be perfect.*

To adjust the transit to the meridian.—The line of collimation by reason of the previous adjustment describes a vertical circle, and, therefore, bisects the zenith, which is one point in the meridian. If, then, we can make it also bisect another point in the meridian, it will move entirely in the meridian. Compute, from the Tables in the Nautical Almanac, the time of Polaris coming to the meridian, and at the computed time bisect the star by the middle vertical wire, and the transit will be very nearly adjusted to the meridian.

To make the great vertical circle described by the line of collimation more nearly coincident with the meridian, let the intervals between the successive passages of Polaris across the meridian be observed as indicated by the instrument. Then, if the interval between the inferior and superior passage be equal to the interval between the superior and inferior, the adjustment to the meridian is perfect; but if the interval between the inferior and superior passage be less than the interval between the superior and inferior, the circle described by the line of collimation deviates to the eastward of the true meridian, from the zenith to the north point of the horizon, and to the westward, from the zenith to the south point of the horizon; while if the interval between the inferior and superior passage be the greater, the deviation is in the contrary directions.

Let δ be the observed difference of the intervals from twelve hours, or half the difference between the two intervals in seconds, π the polar distance of the star

* The horizontal motion given to the Y, by the azimuthal screw S, forms, evidently, no part of he adjustment for collimation, but only enables us to examine if the adjustment has been made ith sufficient exactness.

Polaris, and L the latitude of the place; then, Z representing the deviation from the meridian in time, the value of Z will be given by the logarithmic formula

$$\log. Z = \log.\frac{\delta}{2} + \log. \sec. L + \log. \tan. \pi - 20.$$

EXAMPLE.

Place of observation, Cambridge, latitude 52° 12′ 36″

Polar distance of Polaris 1° 39′ 25″·05.

Difference of intervals from 12 hours $7^m\ 22^s = 442^s$.

$\frac{\delta}{2} = 221$	log. =	2·3443923
L = 52° 12′ 36″	log. sec. =	10·2127030
π = 1° 39′ 25″·05	log. tan. =	8·4513064
Z = 10^s·195	log. =	21·0084017

To determine the value of a revolution of the azimuthal screw S, the time of passage of an equatorial star across the middle vertical wire must be noted one day; and, then, turning the screw S once round, the time of passage * must be noted again; and the difference of these times will be the value in time of a revolution of the screw. Suppose the difference thus observed to amount to two seconds, then the value of one complete revolution of the screw S is two seconds, and the value of the motion of the adjusting screw being thus obtained, must be reduced to the horizon, by increasing it in the ratio of cosine of latitude to radius, and may then be applied to correct the error of deviation as found above.

A second method, founded on the same principles as the preceding, consists in observing the pole star, and another star which crosses the meridian near the zenith of the place of observation. The time of passage of such a star, Capella, for instance, when near its superior transit, across the middle wire of the telescope, will differ but very little from the time of passing the true meridian, if the deviation of the instrument from the meridian be but small. Assume the two times to agree exactly, and the difference between the times of superior transit of Capella and Polaris will be the difference of the observed right ascensions of these two stars. From this difference subtract the difference of the computed, or catalogued, right ascensions of the stars, and call the result D; and the deviation will be given by the formula

$$\log. Z = \log. D + \log. \sin. \pi + \log. \sec. (L + \pi),$$

π being the polar distance of Polaris, and L the latitude of the place of observation. From Capella not having been exactly on the meridian, when on the middle vertical wire, the value of D, as above obtained, is only an approximation to the error of the observed right ascension of Polaris, and the deviation computed from it will be only approximately correct; but, by repeating the operation, the adjustment may be completely perfected.

D is actually the value of the sum of the errors of the observed right ascensions of Capella and Polaris, and hence the value of Z will be correctly given, by so considering it, instead of supposing as above, that this is error, for Capella is zero. The true deviation then is given by the formula

$$\log. Z = \log. D + \log. \sin. \pi + \log. \sin. \pi' + \log. \operatorname{cosec}. (\pi' - \pi) + \log. \sec. L.$$

π' being the polar distance of Capella.

* The time here spoken of, and throughout the description of this instrument, unless otherwise expressly stated, is sidereal, and not mean time.

Using this last formula, the method may be applied to Polaris, and any star distant from the pole, or to any two stars differing from each other not less than 40° in declination. If, however, the transit of one star is observed above, and of the other below the pole, the formula will be

$$\log. Z = \log. D + \log. \sin. \pi + \log. \sin. \pi' + \log. \operatorname{cosec}. (\pi' + \pi) + \log. \sec. L.$$

Considerable advantage may be obtained by selecting two stars that differ but little in right ascension, as there is then the less probability of error from a change in the rate of the clock, or in the position of the instrument, on which account such methods are to be preferred in temporary observatories, where the stability of the instrument is not to be depended upon for any length of time.

In all the preceding formulæ, the deviation from the meridian is given in time; but to convert it into angular measure, if desirable, we have only to multiply by 15, and the seconds of time will be converted into seconds of a degree.

When the instrument is by any of the methods explained above brought into the meridian, a distant mark may be set up in the plane of the meridian, by which the adjustment to the meridian may afterwards be tested.

Method of observing with the transit.—The adjustments having been completed, in making observations with the instrument, the instant of a star's passing the middle vertical wire will be the time of the star's transit; but the time of the star's passing all the five wires must be noted, and the mean of the times, taken as the time of transit, will be a more accurate result than the time observed at the middle wire only.

When the sun is the object observed, the time of the centre of his disc passing the middle wire is the time of transit; but as it would be impossible to estimate this centre with accuracy, the time of both his limbs coming into contact with each wire in succession is to be noted, and a mean of all these times will be the time of transit required. This mean may be conveniently taken, by writing the observed times of contact of the first and second limbs underneath each other in the reverse order, when the sums of each pair will be nearly equal.*

EXAMPLE.

	s	s	h m s	s	s	
1826. Sept. 23.	20·4	38·7	11 58 57·0	15 5	33·7	⊙ 1 limb.
	42·3	24·0	12 1 5·7	47·2	28·7	⊙ 2 limb.
	2·7	2·7	24 0 2·7	2·7	2·4	The sum = 13·2

The time of either limb passing the centre wire is recorded in full, but for the other wires, the seconds only are recorded, as the sums of the several pairs only differ by decimals of a second. Half the sum of the times at the middle gives, then, the correct time of transit as far as the seconds, and the decimals are found by removing the decimal point one place to the left in the sum 13·2, which is equivalent to dividing by 10. Then the time of transit, or mean of observations in the above example, is $12^h\ 0^m\ 1^s{\cdot}32$. This example is taken from observations made with a large transit; and, if with a smaller instrument the sums of the several pairs of observations should differ by more than a second, it will be necessary to take the sums of both figures of the seconds, and the division by 10, performed as above, will give the last figure of the seconds, as well as the decimals.

* This is Dr. Pearson's method.

In taking transits of the moon, the luminous edge alone can be observed, from which the time of transit of the centre must be deduced by the aid of Lunar tables.

In observing the larger planets, one limb may be observed at the first, third, and fifth wires, and the other at the second and fourth, and the mean of these observations will give the transit of the planet's centre.

It will sometimes happen that from the state of weather, or from some other cause, a heavenly body may not have been observed at all the wires; but if the declination of the body be known, an observation at any one of the wires may be reduced to the central wire, so as to give the time of transit, as deduced from this observation. If an observation be obtained at more than one wire, the mean of the times of passing the centre, as deduced from each wire observed, is to be taken as the time of transit. The reduction to the centre wire is given by the formula

$$\mathrm{R} = \mathrm{V}\ \mathrm{cosec.}\ \pi, \text{ or } \log.\ \mathrm{R} = \log.\ \mathrm{V} + \log.\ \mathrm{cosec.}\ \pi;$$

in which R represents the Reduction, π the polar distance of the body observed, and V the equatorial interval from the wire, at which the observation has been made, to the central wire. The equatorial intervals for each side wire must, therefore, be carefully observed, and tabulated for the purpose of this reduction. The formula $\mathrm{R} = \mathrm{V}\ \mathrm{cosec.}\ \pi$ is only an approximate value of the reduction, and with large instruments capable of giving results within $0''{\cdot}05$, a further correction is necessary for bodies within 10° of the pole. The whole reduction in this case is given by the formula

$$\mathrm{R}' = \tfrac{1}{15}\ \mathrm{sin.}^1\ 15\ \mathrm{V}\ \mathrm{cosec.}\ \pi.$$

The time of any star's passage from one of the side wires to the centre wire being observed, the equatorial interval from that wire to the centre is obtained by multiplying the observed interval by the sine of the star's polar distance; and the equatorial intervals being deduced in this manner from a great many stars, the mean of the results may be considered as very correct values of the equatorial intervals required. No star very near the pole should, however, be taken for this purpose.

Use of the portable transit.—The large transits in permanent observatories are used to obtain, with the greatest possible accuracy, the right ascensions of the heavenly bodies, from which, and the meridian altitudes observed by a mural circle, an instrument consisting of a telescope attached to a large circle, and placed in the plane of the meridian, nearly all the data necessary for every astronomical computation are obtained. For such purposes the small portable transit is not adapted; but it is competent to determine the time to an accuracy of half a second, to determine the longitude by observations of the moon and moon culminating stars, and to determine the latitude by placing it at right angles to the meridian, or in the plane of the prime vertical.*

The transit of the sun's centre gives the apparent noon at the place of observation, and the mean time at apparent noon is found by subtracting or adding the equation of time, as found in the Nautical Almanac, to 24 hours.† The difference between the mean time, thus found, and the time of the sun's transit, as shewn by a clock or

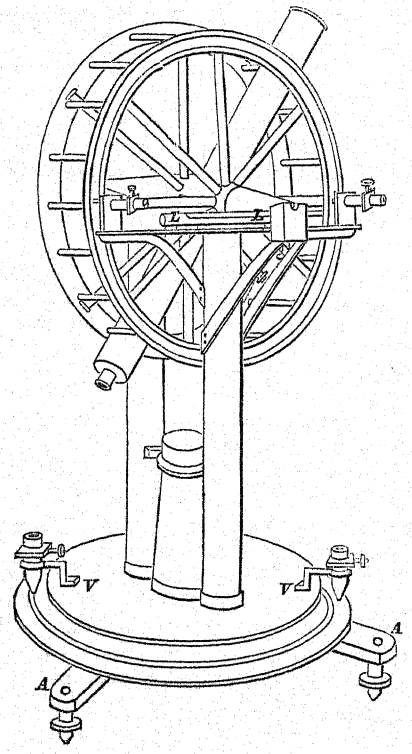
* The prime vertical is the great circle which passes through the zenith and the east and west points of the horizon.

† The astronomical day commences at noon, and contains 24 hours, the hours after midnight being called 13, 14, &c., and the day ends at the next noon. The equation of time is given in the Nautical Almanac for apparent noon at the meridian of Greenwich, and the correction to give the equation of time at any other meridian will be found by multiplying the difference for one hour, as given in the almanac, by the longitude of the place, estimated in time.

chronometer, is the error of the clock or chronometer for mean time at the place of observation.

The time shewn by a sidereal clock when any heavenly body crosses the meridian should coincide with the right ascension of that body, as given in the Nautical Almanac. The difference between the time shewn by the sidereal clock, at the transit, and the right ascension of the body, taken from the almanac, will, therefore, be the error of the clock, +, or too fast, when the clock time is greater than the right ascension, —, or too slow, when it is less.

The Portable Altitude and Azimuth Instrument.—The bending of an unbraced telescope renders it unfit for the determination of altitudes; but by placing the telescope between two circles braced together, an instrument may be formed capable of observing both the meridian altitudes and times of transit of the heavenly bodies. The increased weight of the instrument, however, must now be prevented from producing flexure in the horizontal axis, and this has been very ingeniously accomplished by Troughton. By mounting the transit and altitude instrument, as Troughton's transit-circle may be called, upon a horizontal plate or circle having an azimuthal motion round a vertical axis, an instrument is formed by which observations may be made either in or out of the meridian. When constructed of a portable size, the altitude and azimuth instrument may also be used in important surveying operations; for, in fact, it may be considered as a rather large theodolite of superior construction.



The altitude and azimuth instrument may be considered as consisting of three parts: 1, the tripod carrying the vertical axis about which the instrument turns; 2, the horizontal revolving plate carrying the vertical pillars, with their appendages; and 3, the vertical circles with the telescope.

The tripod A A, is supported by three foot-screws, by which the vertical axis is brought into adjustment, and carries the lower horizontal plate, which is graduated to show the azimuths or horizontal angles. The vertical axis is a solid metallic cone rising from the centre of the tripod to a height about equal to the radius of the horizontal circle.

The upper horizontal plate, or horizontal revolving plate, V V, carries an index, to point out the graduation, upon the lower horizontal plate, or azimuth circle, which denotes nearly the angle to be read off. The graduations upon the azimuth circle, as well as upon the vertical circle, are subdivided by reading microscopes, the construction and adjustments of which we shall presently explain. The reading microscopes of the

azimuth circle are attached to the revolving plate V V, which also carries two upright pillars. From the centre of the upper horizontal plate, V V, rises a hollow brass cone which just fits over and moves smoothly upon the solid metallic vertical axis rising from the tripod stand. A horizontal brace connects the two upright pillars with one another and with the top of the hollow brass cone, and keeps the pillars firm and parallel to one another. On the top of each pillar a gibbet piece is fixed, projecting beyond the pillars, and upon the extreme ends of these pieces are carried the y's for supporting the pivots of the horizontal, or transit axis. The y's are each capable of being raised or lowered by turning a milled-headed screw. The top of one of the pillars carries a cross piece for supporting the two reading microscopes of the vertical circle; and to this cross piece is attached the level L L, by which the adjustment of the vertical axis is denoted.

The third portion of the instrument consists of the vertical circle and its telescope. This circle consists of two limbs firmly braced together, and preventing any tendency to flexure in the tube of the telescope, by affording it support at the opposite ends of a diameter. One of the limbs only is graduated, and the graduated side is called the face of the instrument, and the clamp and tangent screw, for giving a slow motion to the vertical circle, act upon the ungraduated limb, and are fixed to the vertical pillar on the side of that limb. The horizontal axis which supports the telescope and vertical circle is constructed exactly as the axis of the transit instrument; but as it might press too heavily on the y's from the increased load of the vertical circle, a spiral spring, fixed in the body of each pillar, presses up a friction roller against the conical axis with a force which is nearly a counterpoise to its weight. The adjustment of the horizontal axis is denoted by a striding level, as in the portable transit.

ADJUSTMENTS.

Adjustments of the vertical axis.—Turn the instrument round till the level, L L, is over two of the foot-screws, and adjust the level, so that its bubble may retain the same position, when the instrument is turned half-round, so that the level is again over the same foot-screws, but in the reverse position. The error at each trial is corrected, as nearly as can be judged, half by the foot-screws, and half by the adjusting screw of the level itself.

Next turn the instrument round 90° in azimuth, so that the level, L L, may be at right angles to its former positions, and bring the bubble to the same position as before, by turning the third foot-screw. Repeat the whole operation till the result is satisfactory.

Adjustment of the horizontal axis.—This adjustment is performed in the same manner, as already described for the transit instrument, with the single exception that one end of the axis is to be raised or lowered, if necessary, by the screw acting upon its y, and not by moving a foot-screw, which would derange the previous adjustment.

Adjustment of the circle to its reading microscopes.—This is performed by raising or lowering both the y's equally, so as not to derange the previous adjustment, till the microscopes are directed to opposite points in its horizontal diameter.

Adjustment of collimation in azimuth.—Instead of taking the axis out of its bearings and turning it end for end, the whole instrument is turned round in azimuth; but in all other respects the method of performing this adjustment is the same as that already described for the transit instrument.

Adjustment of collimation in altitude.—Point the telescope to a very distant object, or star, and, bisecting it by the cross wires, read off the angle upon the vertical circle denoted by the reading microscopes. Turn the instrument half-round in azimuth, and, again bisecting the same object by the cross wires, read off the angle.

One of these readings will be an altitude, and the other a zenith distance,* and their sum, therefore, when there is no error of collimation in altitude, will be 90°. If the sum is not 90°, half its difference from 90° will be the error of collimation in altitude, and this error being added to or subtracted from the observed angles, according as the sum of the readings is less or greater than 90°, will give the true zenith distance and altitude. The error of collimation in altitude may then be corrected by adjusting the microscopes to read the true zenith distance and altitude, thus found, while the object is bisected by the cross wires of the telescope. The error of collimation of this and other astronomical instruments may also be found, or corrected, by the collimator.

Use of the altitude and azimuth instrument.—In using the altitude and azimuth instrument, for astronomical purposes, double observations should always be made, with the face first to the east, and then to the west, or *vice versâ*, or several observations may be made with the face to the east, and as many with the face to the west, and the mean of the results, reduced to the meridian, taken as the true results. The place for a meridian mark may be determined by the methods already explained when describing the transit instrument, or by observing the readings of the azimuthal circle, or noting the times, when any celestial object has equal altitudes. Since the diaphragm of the telescope is furnished not only with the central horizontal wire, but with other horizontal wires at equal distances above and below it, so that there may be altogether either three or five or seven horizontal wires, the azimuths and times may be observed, when the object observed is bisected by each of these wires. If a fixed star be the object observed, the mean of the times will give the time of the star's passing the meridian, and the mean of the azimuths will give the reading of the azimuth circle when the star was on the meridian, or the correction to be applied to the readings of the azimuth circle to give the true azimuths. If the sun be the body observed, a correction is necessary on account of the change of his declination, during the intervals between the observations.

The correction for the time, as deduced from a pair of equal altitudes of the sun, is given by the formula,

$$\text{Correction} = \frac{\delta}{720} \times \frac{\frac{t}{2}}{\text{sin. } 15^\circ \cdot \frac{t}{2}} (\text{tan. D} \times \text{cos. } 15^\circ \cdot \tfrac{t}{2} - \text{tan. L}), \text{ in which}$$

δ represents the variation in the sun's declination from the noon of the day preceding the observations to the noon of the day succeeding;

t represents the interval between the observations expressed in hours and decimals of an hour;

D represents the sun's declination at noon on the day on which the observations are made;

L represents the latitude of the place.

δ is to be reckoned positive when the sun's declination is increasing, and negative when it is decreasing.

The correction for azimuth is given by the formula,

$$\text{Correction} = \tfrac{1}{2} (\text{D}' - \text{D}) \text{ sec. lat. cosec.} \frac{15}{2} (\text{T}' - \text{T}),$$

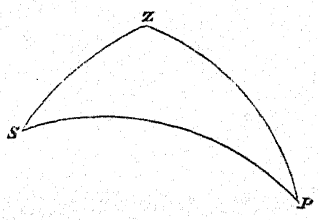
in which D′ − D represents the change of the sun's declination, and T′ − T represents the interval in time, } between the observations.

When the sun is advancing towards the North Pole, this correction will carry the middle point towards the west of the approximate south point; but when he is

* Both the horizontal and vertical circles are usually divided alike into four quadrants, and each quadrant graduated from 0° to 90°, proceeding in the same direction all round the circles.

approaching the South Pole, it will carry the same point towards the east, and must be applied accordingly.

The altitude and azimuth instrument being adapted to observe the heavenly bodies in any part of the visible expanse of the heavens, its powers may be applied at any time to determine the data from which the time, the latitude of the place of observation, or the declination of the body observed, may be at once determined. We subjoin some of the formulæ, adapted to logarithmic computation, connecting the parts of what may be called the *astronomical triangle*, of which the points are, the pole, P, the zenith, Z, and the apparent place of the body observed, S.

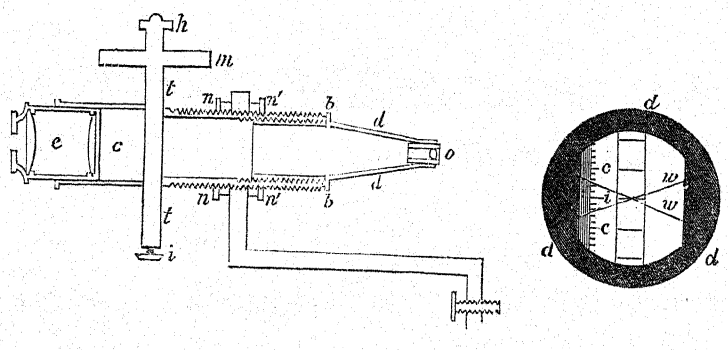


Let P Z, the co-latitude of the place, be represented by λ.
P S, the polar distance of the body observed . . π.
Z S, the zenith distance of the body observed . . Z.
Z P S, the hour-angle from the meridian . . . h.
P Z S, the azimuthal angle . . . . . α.

Then we have the following formulæ for determining the time, the latitude, and the declination of the body observed.

No.	Given.	Required.	Auxiliary Angles.	Formulæ.
1	Z, π, λ	h	. . . . .	$\tan. \frac{1}{2} h = \sqrt{\frac{\sin. \frac{1}{2}(Z + \pi - \lambda) \cdot \sin. \frac{1}{2}(Z + \pi + \lambda) \cdot \sin. \frac{1}{2}(Z + \lambda - \pi)}{\sin. \frac{1}{2}(\pi + \lambda - Z)}}$
2	π, λ, α	h	$\tan \phi = \frac{\cot. \alpha}{\cos. \lambda}$	$\cos. (h \sim \phi) = \frac{\cot. \pi \cos. \phi}{\cot. \lambda}$
3	Z, λ, α	h	$\cot. \phi = \frac{\cot. Z}{\cos. \alpha}$	$\cot. h = \frac{\cot. \alpha \sin. (\lambda \sim \phi)}{\sin. \phi}$
4	Z, π, α	h	. . . . .	$\sin. h = \frac{\sin. Z \sin. \alpha.}{\sin. \pi}$
5	Z, π, α	λ	$\tan. \phi = \cos. \alpha \tan. Z$	$\cos. (\lambda \sim \phi) = \frac{\cos. \pi \cos. \phi}{\cos. Z}$
6	Z, π, h	λ	$\tan. \phi = \cos. h \tan. \pi$	$\cos. (\lambda \sim \phi) = \frac{\cos. Z \cos. \phi}{\cos. \pi}$
7	Z, α, h	λ	$\cot. \phi = \frac{\cot. Z}{\cos. \alpha}$	$\sin. (\lambda \sim \phi) = \frac{\cot. h \sin. \phi}{\cot. \alpha}$
8	π, α, h	λ	$\cot. \phi = \frac{\cot. \pi}{\cos. h}$	$\sin. (\lambda \sim \phi) = \frac{\cot. \alpha \sin. \phi}{\cot. h}$
9	Z, λ, α	π	$\tan. \phi = \cos. \alpha \tan. Z$	$\cos. \pi = \frac{\cos. Z \cos. (\lambda \sim \phi)}{\cos. \phi}$
10	Z, λ, h	π	$\tan. \phi = \cos. h \tan. \lambda$	$\cos. (\pi \sim \phi) = \frac{\cos. Z \cos. \phi}{\cos. \lambda}$
11	Z, α, h	π	. . . . .	$\sin. \pi = \frac{\sin. \alpha \sin. Z}{\sin. h}$
12	λ, α, h	π	$\tan. \phi = \frac{\cot. \alpha}{\cos. \lambda}$	$\cot. \pi = \frac{\cot. \lambda \cos. (h \sim \phi)}{\cos. \phi}$

The Reading Microscope.—The first of the annexed figures represents a longitudinal section of this instrument, and the second represents the field of view, shewing the magnified divisions of the limb of the instrument to which the microscope is applied, and the diaphragm, *d d*, of the microscope, with its comb, *c c*, and cross wires, *w w*. The diaphragm is contained in the box, *t t*, and consists of two parts moving one over



the other,—the comb *c c*, which is moved by the screw *i*, at the bottom of the box, for the purpose of adjustment, and the cross wires *w w*, and index *i*, which are moved over the comb and the magnified image of the limb, by turning the milled head *h*. The micrometer head, *m*, is attached by friction to the screw turned by the milled head, so that by holding fast the milled head, the micrometer head can be turned round for adjustment.

e is the eye-piece, which slides with friction into the cell *c*, so as to produce distinct vision of the spider's lines of the micrometer. The object glass, *o*, is held by a conical piece *d d*, which screws further into, or out of, the body of the instrument, so as to produce distinct vision of the divided limb to be read by the microscope, and, when adjusted, is held firmly in its place by the nut *b b*. The microscope screws into a collar, so as to be capable of adjustment with respect to its distance from the divided limb, and, when so adjusted, is held firmly in its place by the nuts *n n*, *n' n'*.

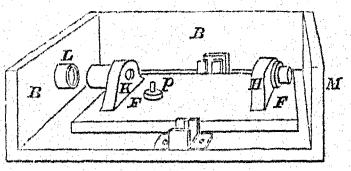
Adjustments of the reading microscope.—Screw the object glass home. Insert the body of the microscope into the collar destined to receive it, and screw home the nuts *n n* and *n' n'*. Make the diaphragm and spider's lines visible distinctly, by putting the eye-piece *e* the proper depth into the cell *c*. Then make the graduated limb also distinctly visible without parallax by turning the nuts *n n* and *n' n'*, unscrewing one and screwing up the other till the desired object is attained.

Now bring the point of intersection of the spider's lines upon a stroke of the limb, and turn the micrometer head *m* to zero; then, turning the screw through five revolutions, if the point of intersection of the spider's lines has not moved over the whole of one of the divided spaces on the limb, the object-lens must be screwed up to diminish the power by turning the cone *d d*: and if it has moved over more than one of the divided spaces, it must be unscrewed to increase the power; and then altering the position of the microscope, by turning the nuts *n n* and *n' n'*, till distinct vision of the limb is again obtained, the measure of the space, moved over by five revolutions of the screw, must be repeated, as before. When, after repeated trials, the result is satisfactory, the three nuts, *n n*, *n' n'*, and *b b*, must be screwed tight home, to render the adjustment permanent.

When the microscope has been thus adjusted for distance, the zero of the division

on the limb must be brought to the point of intersection of the spider's lines, and the divided head, *m*, turned, till its zero is pointed to by its index; and then, if the zero on the comb, *c c*, be not covered exactly by the index *i*, the comb must be moved by turning the screw *i*, which enters the bottom of the micrometer box, till its zero is covered by the index pin. The adjustment of the reading microscope will now be perfect; and the graduated limb to be read by it, being divided at every five minutes, the degree and nearest five minutes of an observed angle will be shewn by the pointer or index to this graduated limb; while the number of complete revolutions, and the parts of a revolution, of the screw, in the order of the numbers upon the micrometer head, *m*, required to bring the point of intersection of the spider's lines upon a division of the graduated limb, will be the number of minutes and seconds, respectively, to be added to the degrees and minutes shown by the index of the circle. The complete revolutions, or minutes, to be added, are shewn by the number of teeth the index *i* has passed over from zero, and the parts of a revolution, or seconds and tenths to be added, are pointed out upon the micrometer head, *m*, by its index.

The Collimator.—B B is a rectangular mahogany box partly filled with mercury. F F is a float of cast iron partly immersed in the mercury. Two iron bearing pieces are screwed to the bottom of the box by short iron screws; and each of these pieces has two vertical plates turned up, the inner one of which has a longitudinal slit in it, into which slit iron pivots, screwed into the sides of the float, are admitted. The use of these parts is to keep the sides of the float parallel to the sides of the box, and at an inch, or more, from contact with any part of the box, that the mercury may assume a flat surface. H and K are two holding pieces of metal cast along with the float, and are perforated to receive each a socket. The socket at H receives an achromatic object-glass, and is adjustable by a screw for its focal distance, and the socket at K holds two cross wires; while another socket, let into the end of the box at L, carries a lens forming an eye-piece; so that the collimator is in fact an astronomical telescope with a system of cross wires in the common focus of the object-glass and eye-lens. The inclination, as compared with the surface of the fluid, of the optical axis of this telescope, or of the line joining the centre of the object-glass and the intersection of the cross wires can be modified by the addition of perforated pieces of iron, held steady by the vertical pin P, and by their weight depressing the end of the float. The mercury must be as pure as can be obtained, and particles of dust must be constantly excluded by a lid that covers over the top of the box. At M is a circular hole, closed when the instrument is not in use, through which the telescope, of which the error of collimation is sought, is to be directed; and a lamp is placed behind the eye lens at L, to illuminate the cross wires.



Use of the collimator with an altitude and azimuth instrument.—Place the collimator in the plane of the meridian on the south side of the observatory, and direct it so that the cross wires of the telescope of the altitude and azimuth instrument may be seen through it, in the centre of the field of view; then also will the cross wires of the collimator be seen through the telescope in the centre of its field of view. Read off the altitude of the cross wires of the collimator, and then, turning the instrument half-round in azimuth, observe again the cross wires of the collimator, and read off the angle upon the vertical limb, which will now be a zenith distance. The difference between the sum of these readings and 90° is the correction which is to be applied to the altitudes and zenith distances observed with the instrument.

Example.—The sun's meridian altitude had been observed on the 20th December, 1826, and the following determination of the error was made immediately after the observations were finished; viz.

Before reversion the apparent altitude of the cross wires was			0° 1′ 2″·33	
After reversion the apparent zenith distance of the cross wires was			89 58 10 ·33	
Sum			89 59 12 ·66	
Defect from 90°			47 ·33	
Correction of errors of collimation &c.			23 ·66	
Altitude of cross wires corrected	=	1′ 2″·33 + 23 ·66	= 1 26 ·00	
Zenith distance	=	89° 58′ 10″·33 + 23 ·66	= 89 58 34 ·00	
			90 0 0 0 ·00	

The collimator may also be used for a meridian mark with the transit instrument. When used with a circle for measuring altitudes and zenith distances, which has no motion in azimuth, the collimator must be moved from the north to the south side of the observatory, and the mean of the observations in each of these two positions will give the correction for the errors of collimation, &c., as above.

J. F. H.

OBSERVATORY, MAGNETICAL.*—Terrestrial Magnetism is the power which, acting upon a magnetic needle freely suspended by its centre of gravity, causes it to take up a certain position, called the magnetic direction, and also to tend to return to the same position if by any means it is withdrawn from that direction.

The direction of the needle is referred to two planes, the horizontal plane passing through the centre of the needle, and the vertical plane passing through the centre of the needle and the meridian of the place. The angle formed with the horizontal plane is called the inclination or dip, and that with the vertical plane, the declination or variation of the needle. As the magnetic direction and likewise the magnetic force vary at different parts of the earth's surface, it is necessary, in order to obtain a knowledge of the distribution of terrestrial magnetism, to ascertain for various geographical positions—

1st, The direction of the needle;

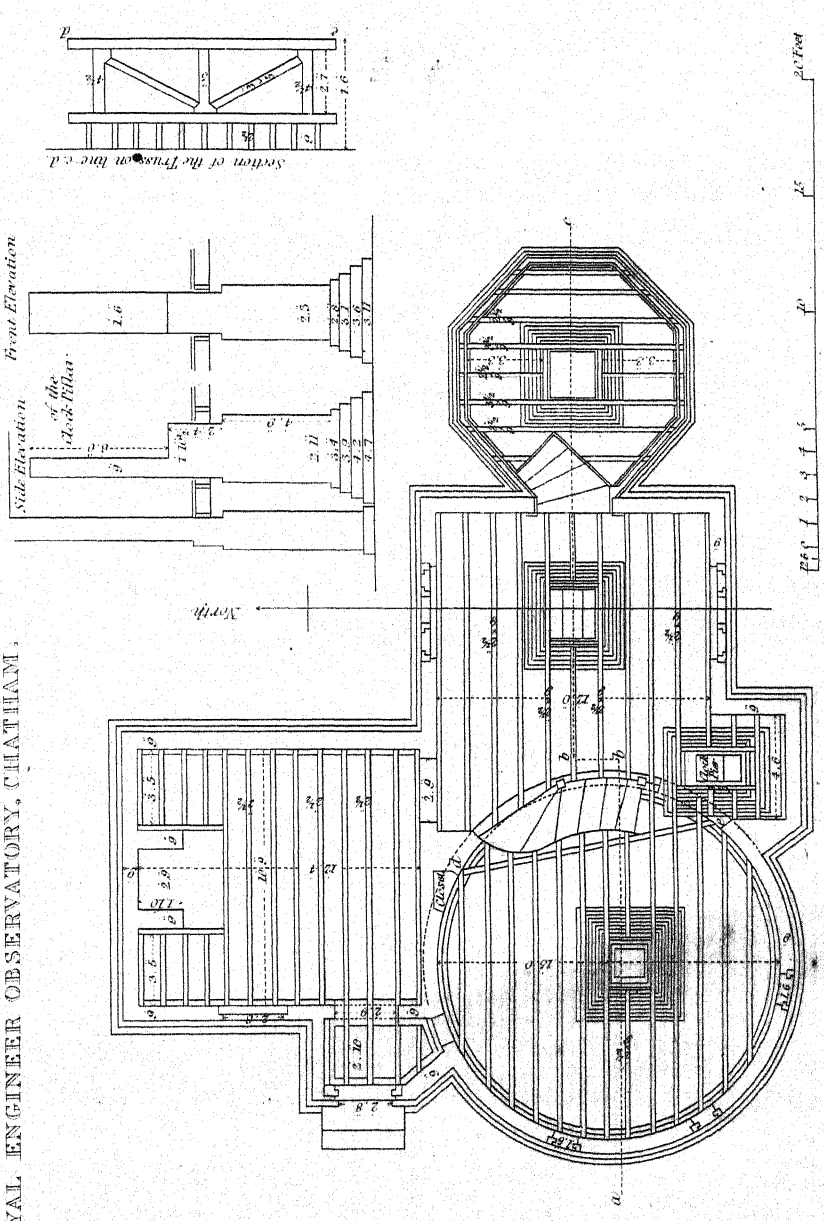
2ndly, The force by which the needle is retained in that direction; and

3rdly, The laws which govern the changes which take place both in direction and force.

The determination of the absolute values of the magnetic elements may be made at any station, independently of the co-operation of observers elsewhere: when a sufficient number of such observations shall have been made, (a work of some considerable magnitude,) charts might be constructed, shewing the values of the declination, inclination, and intensity over the surface of the globe; but even then the demands of the practical navigator, still more of the theoretical inquirer, would be far from satisfied: it would be found, that at the same spot the magnetic elements are subject to irregular fluctuations, the laws in respect to which are wholly unknown, and that on repeating the absolute observations after a lapse of time, the mean values themselves had undergone considerable change, whereby the whole aspect of the magnetical phenomena, correctly delineated at one epoch of time, had become entirely altered. To endeavour to obtain a knowledge of the laws by which these

* By Lieut.-Col. C. W. Younghusband, Royal Artillery.

ROYAL ENGINEER OBSERVATORY, CHATHAM.



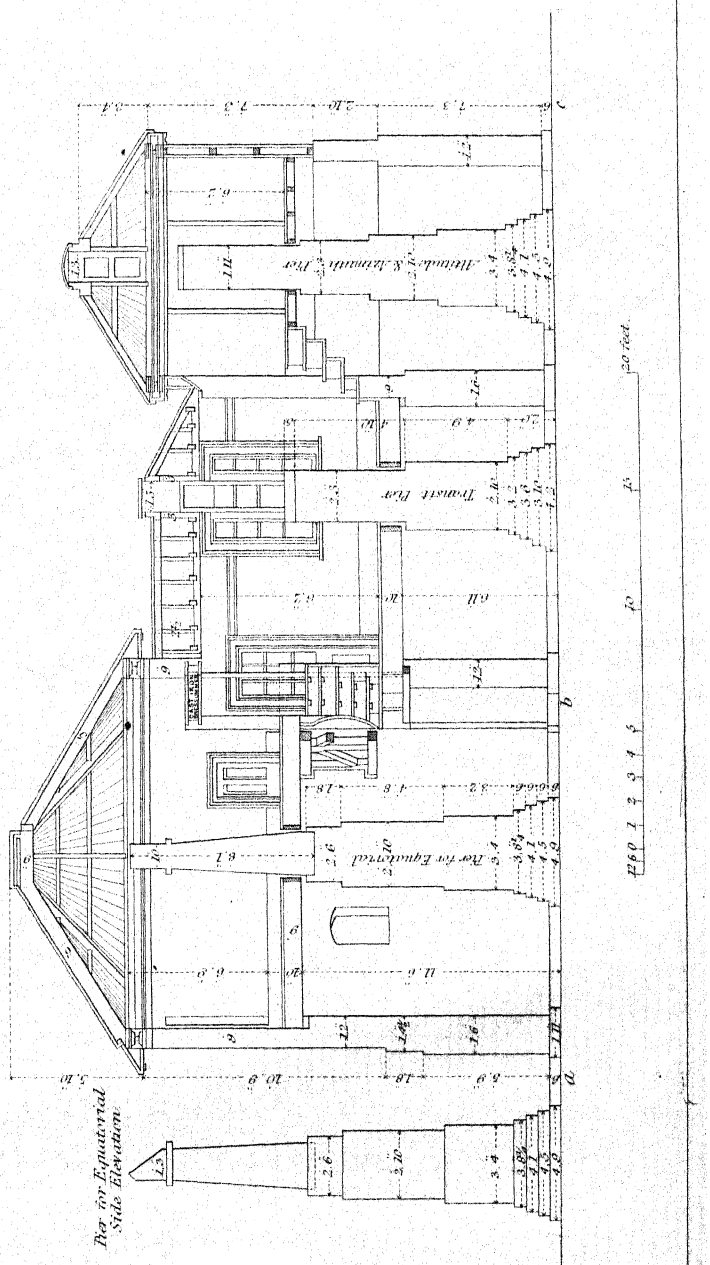
Taken from the 7th Vol.
of Professional Papers

J.W. Lowry fc.

ROYAL ENGINEER OBSERVATORY, CHATHAM.

Section on the Line a b c. Plate 1.

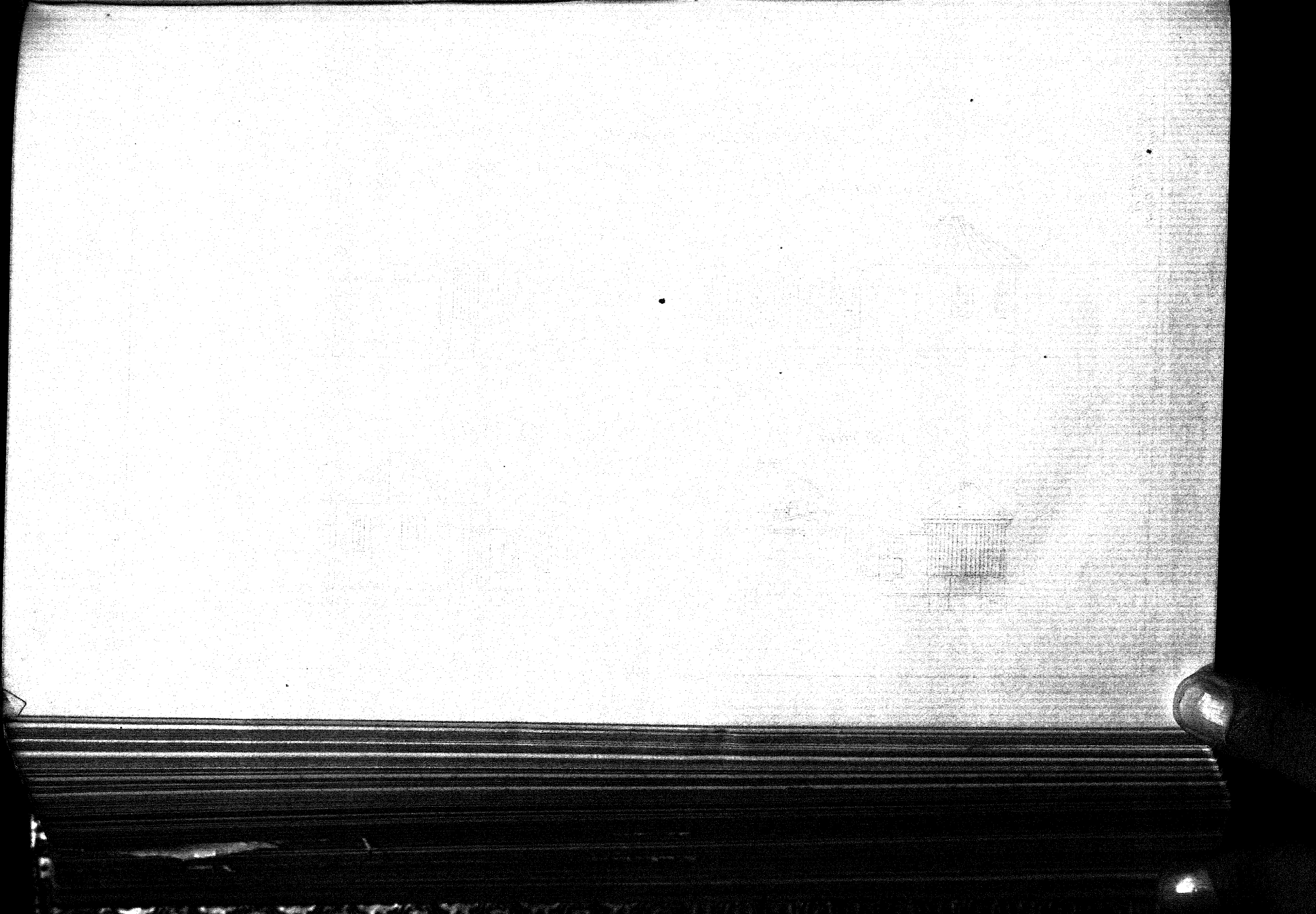
Through the Equatorial Transit and Altitude and Azimuth Rooms.



Taken from the 7th Vol of Professional Papers

J.W. Lowry fe.

London, John Weale, High Holborn 1849.

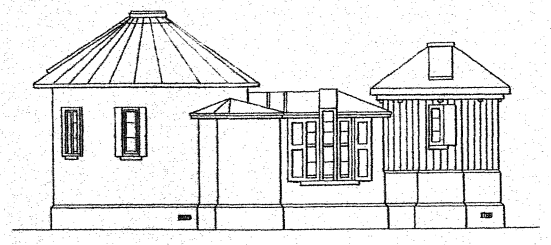


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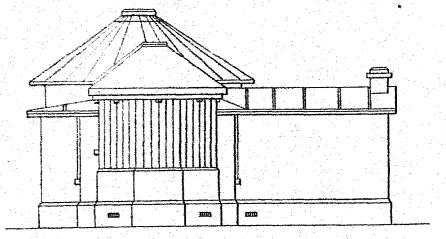
Engraved by John Wells Hugh Hebern RSA

ROYAL ENGINEER OBSERVATORY, CHATHAM.

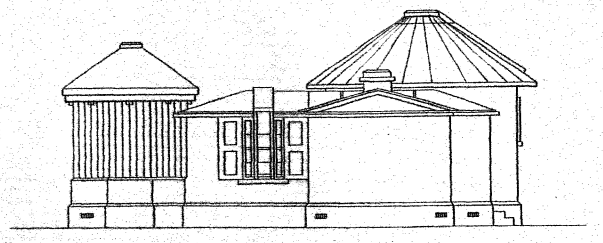
South Front



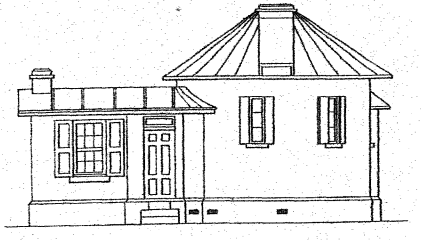
East Front



North Front



West Front



10 5 0 10 20 30 feet.

J.M. Lowry, Jr.

OBSERVATORY, ASTRONOMICAL. PLATE 3

ROYAL ENGINEER OBSERVATORY, CHATHAM.

Fig. 1.

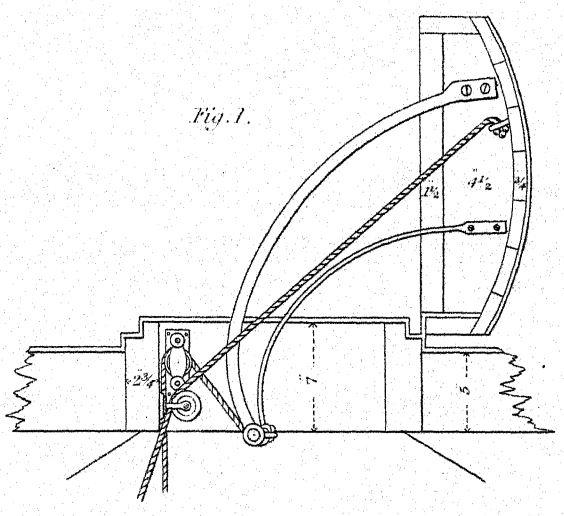


Fig. 2.

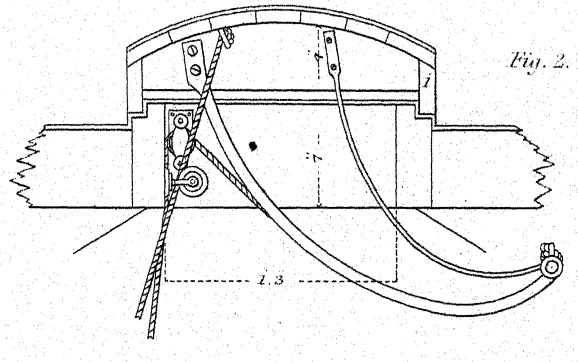


Fig. 3.

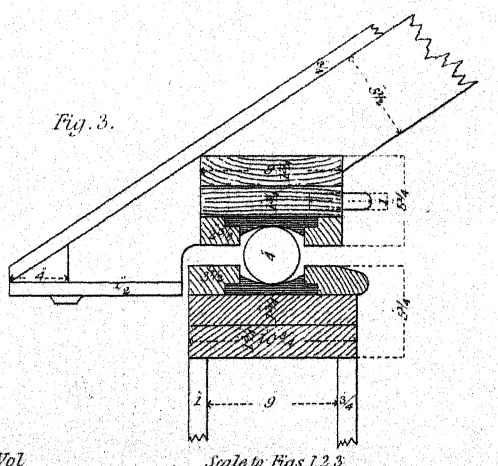


Fig. 1 Is a Section through the top of the Dome Open
Fig. 2 ..... do ..... Shut
Fig. 3 Shews the construction of the lower part of the dome and how it is supported upon the walls. Six balls are used. M is one of the oak pins which are placed at intervals of 6½ inches round the dome for a lever to work against in turning it round.

Taken from the 7th Vol of Professional Papers

Scale to Figs 1.2.3.

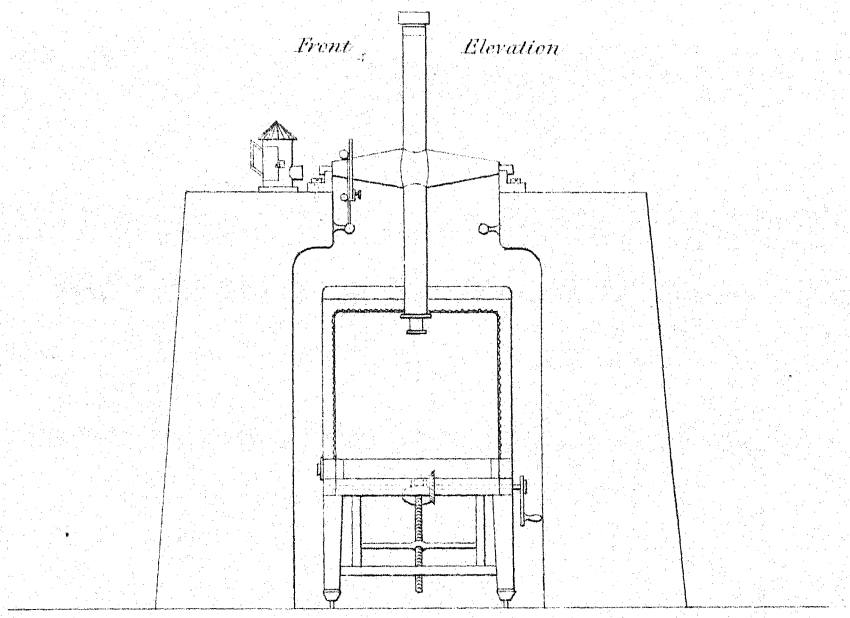
12 9 6 3 0 1 Foot

J.W.Lowry fc.

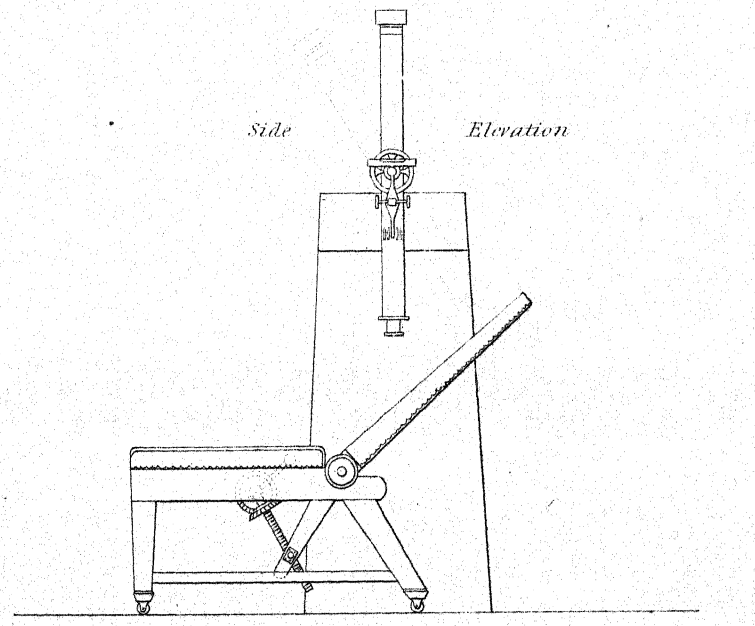
London, John Weale High Holborn. 1849.

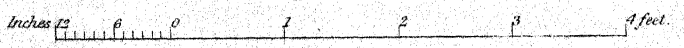
PROPOSED METHOD OF MOUNTING THE SMALLER CLASS OF TRANSIT INSTRUMENTS.

Front Elevation



Side Elevation





J.G.M.

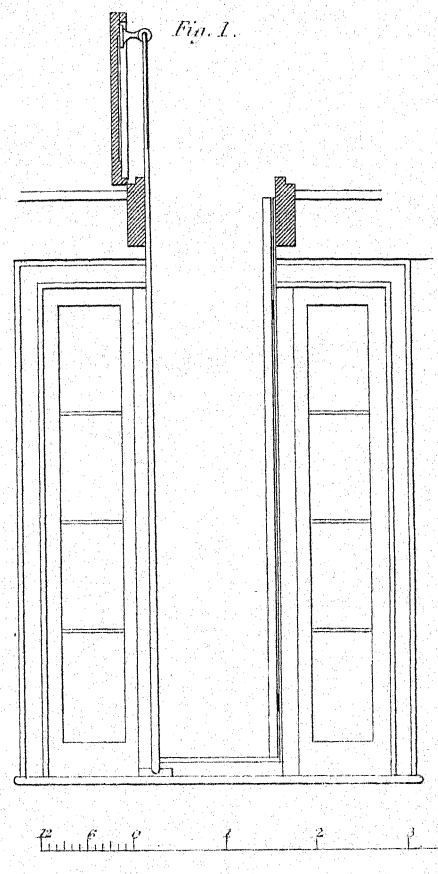
J.W.Lowry fc.



SHEWING THE METHOD OF OPENING AND KEEPING OPEN THE TRANSIT SHUTTERS
R.E. OBSERVATORY CHATHAM.

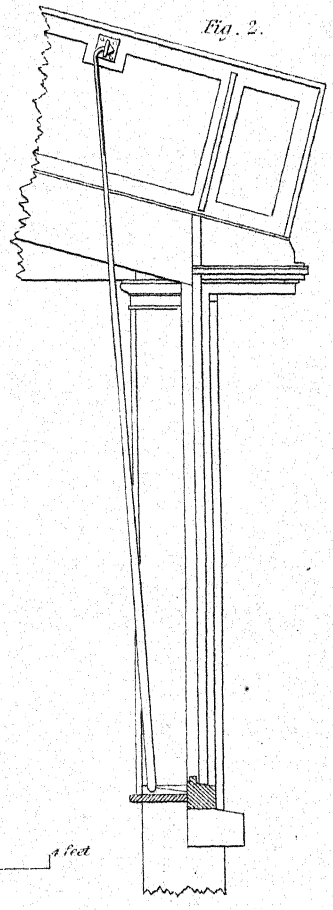
Front Elevation

Fig. 1.



Side Elevation

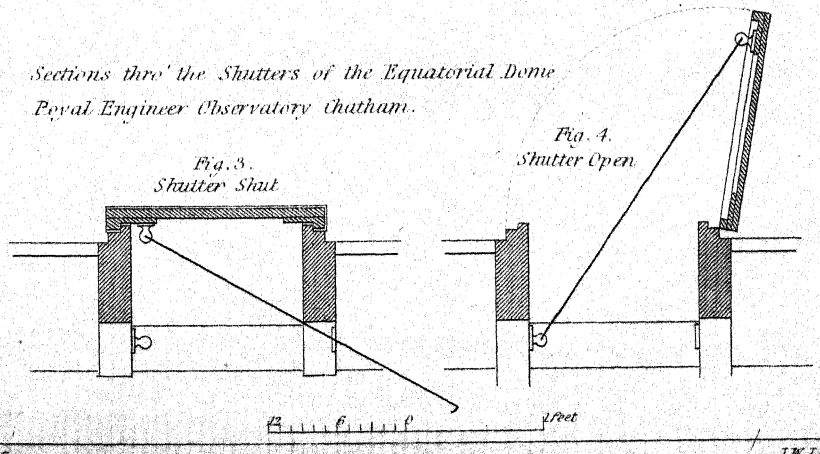
Fig. 2.



Sections thro' the Shutters of the Equatorial Dome
Royal Engineer Observatory Chatham.

Fig. 3.
Shutter Shut

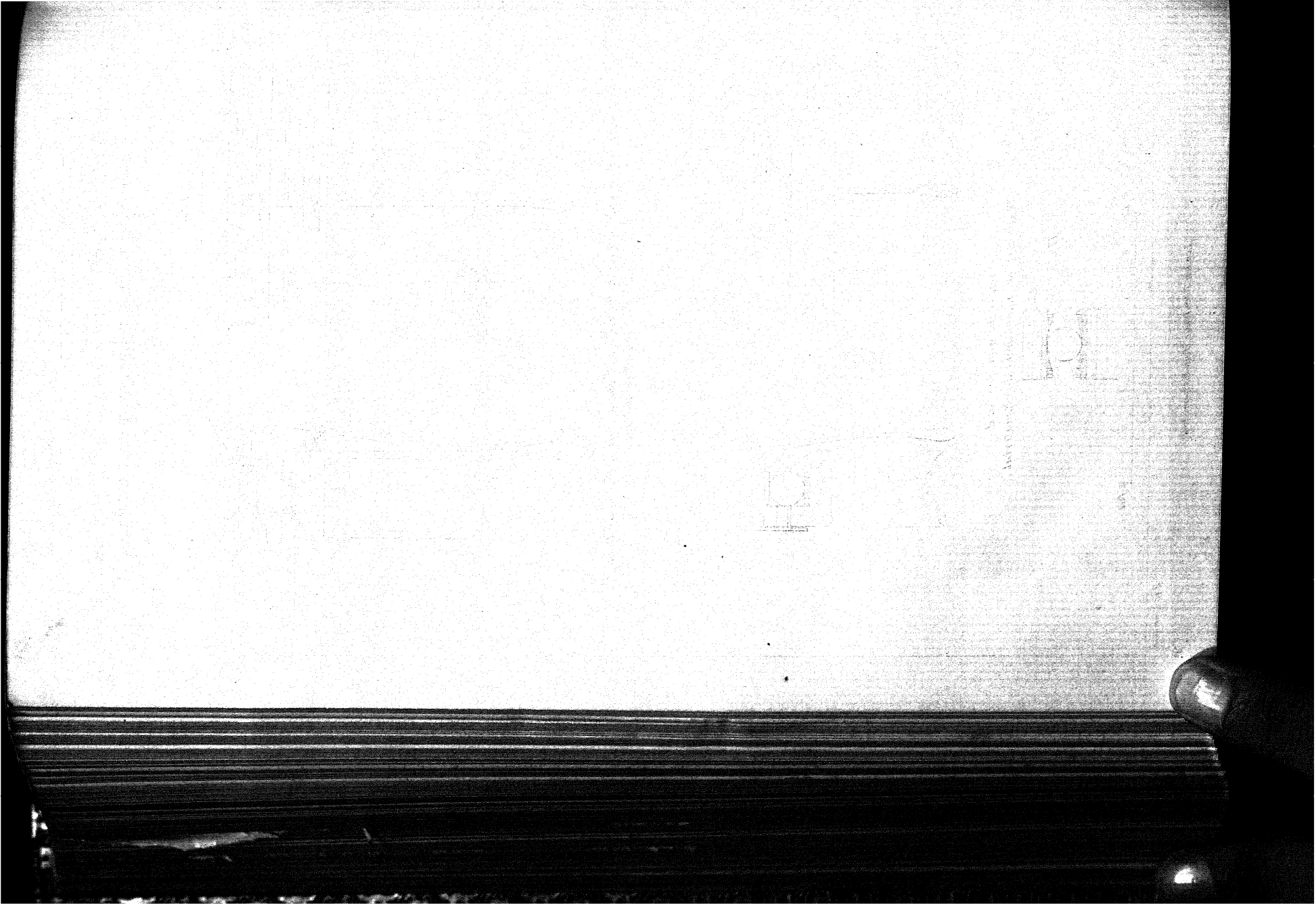
Fig. 4.
Shutter Open



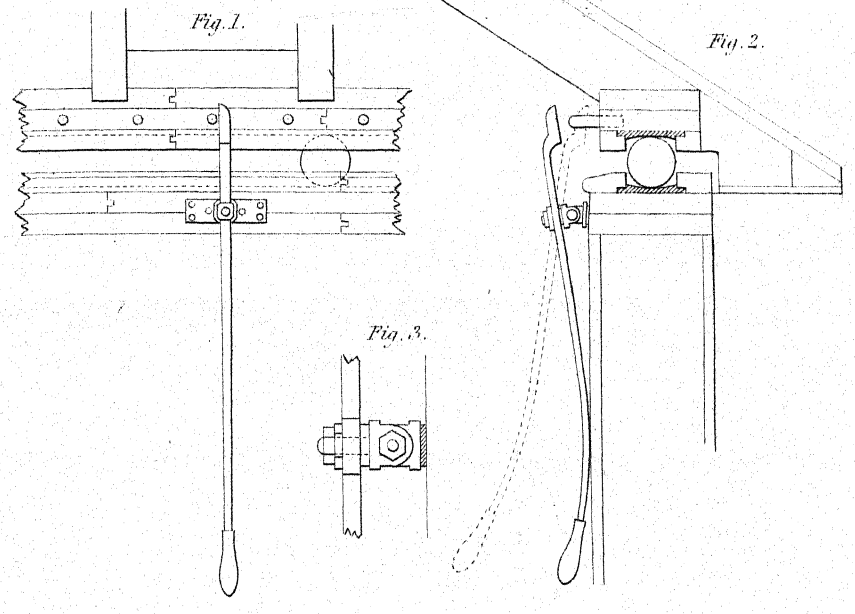
J.G.M.

J.W.Lowry fc.

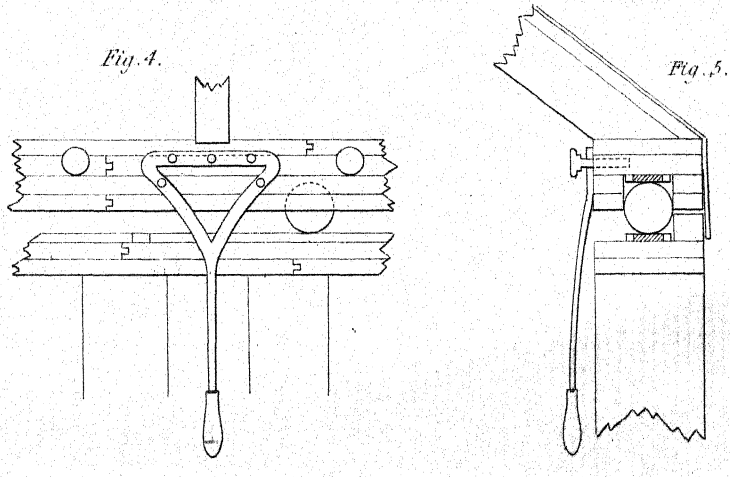
London, John Weale High Holborn. 1848.



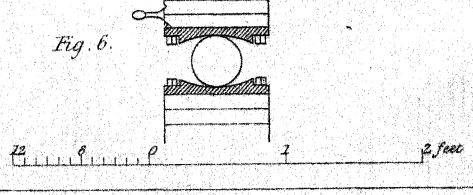
ELEVATION AND SECTION OF THE CURB AND MOVING LEVERS OF THE EQUATORIAL DOME R.E. OBSERVATORY CHATHAM.



Elevation and Section of the curb and hand pins of the small Dome Royal Engineer Observatory.



Section of the wall curb and lower curb of Dome Cambridge Equatorial.



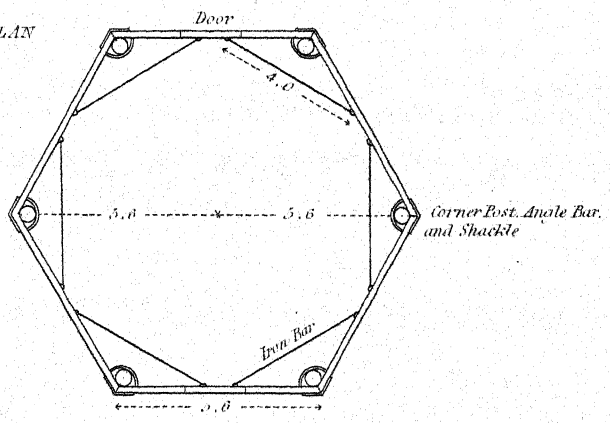
J.G.M. J.W. Lowry fc.

London, John Weale, High Holborn, 1849.

PORTABLE OBSERVATORY.

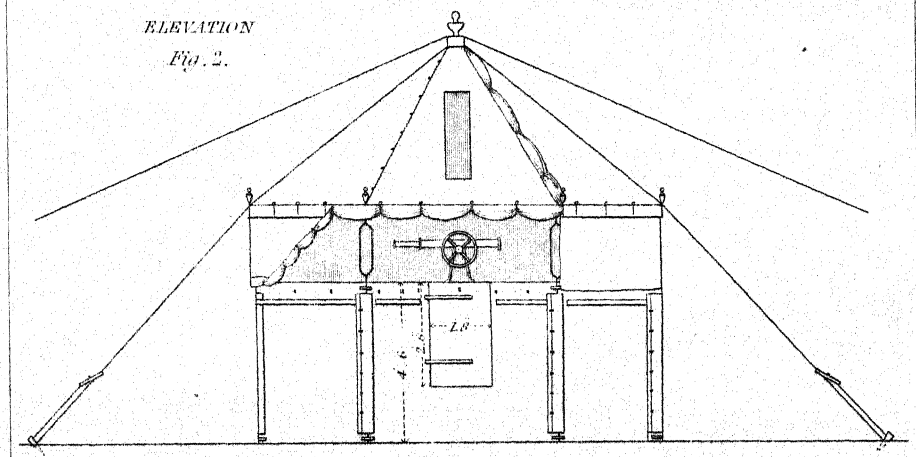
Used on the Ordnance Survey for the largest class of Theodolites Viz. the 3 Feet.

GROUND PLAN
Fig. 1.



Shewing part of Curtain rolled up and side of Roof open for observing the Pole Star.

ELEVATION
Fig. 2.



Scale of Feet

10 5 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 feet

J.W. Lowry fc.

London, John Weale, High Holborn, 1849.

PORTABLE OBSERVATORY.

SKELETON SECTION of Fig. 2 shewing four out of the six Upright Posts and Rafters.

Fig. 3.

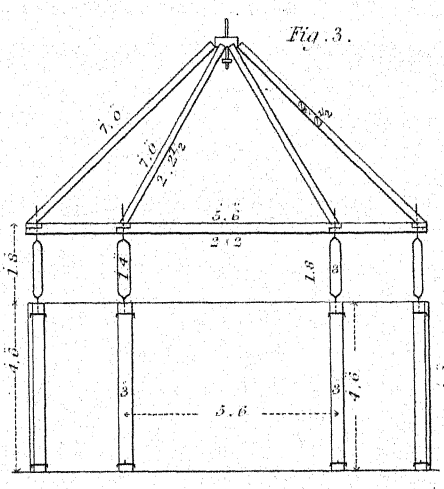


Fig. 4.

Inside View of Panel

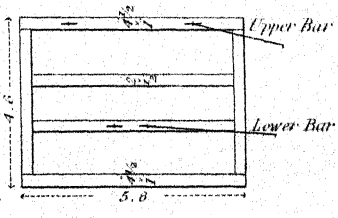


Fig. 5.

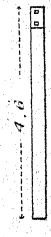


Fig. 6.

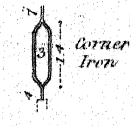


Fig. 7.

Iron Angle Bar



Fig. 8.

Iron Shackle



PORTABLE OBSERVATORY

Used on the Ordnance Survey for the 12 inch or 10 inch Theodolites.

SKELETON SECTION.

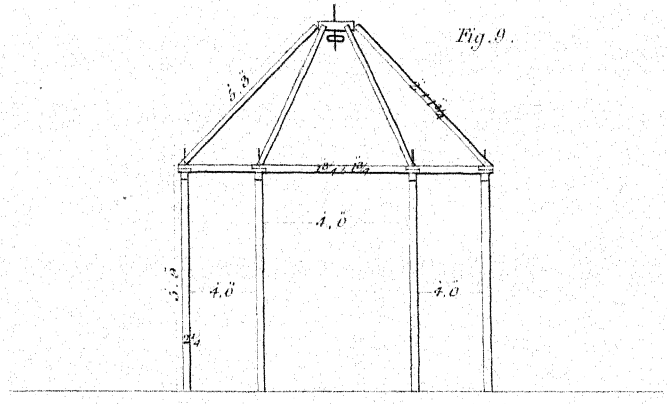


Fig. 9.

FRONT VIEW

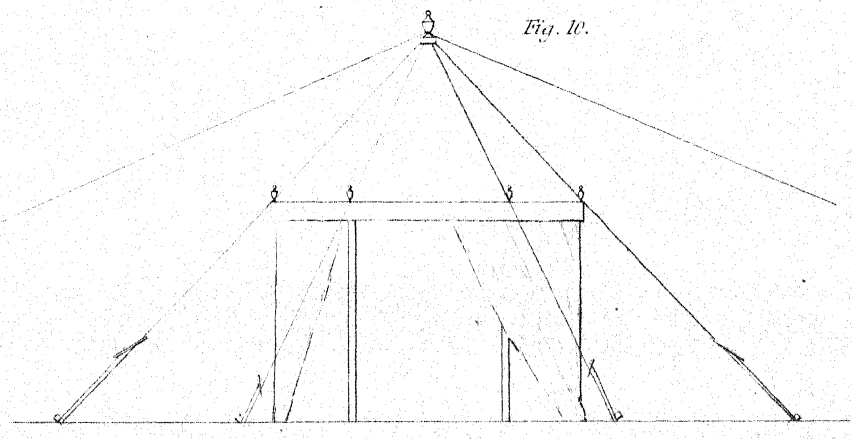


Fig. 10.

Scale of Feet

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 Feet

J.W. Lowry fc.

London John Weale, High Holborn, 1849.

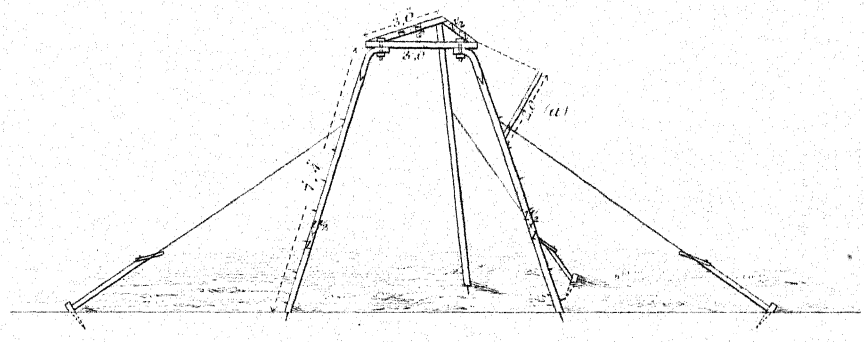
PORTABLE OBSERVATORY.

Used on the Ordnance Survey for the smaller Theodolites

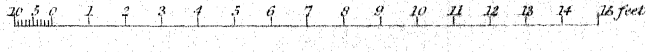
Viz. the 7 Inch &c.

Fig. II.

SUPPORT FOR THE CANVAS



Scale of Feet.



(a) A piece of Stick or Wood 2 feet long notched at foot for Canvas head when required lifting.

J. W. Lowry fe.

London. John Weale High Holborn. 1849.

PORTABLE OBSERVATORY

for the Zenith Sector

Fig. 12.

GROUND FRAME.

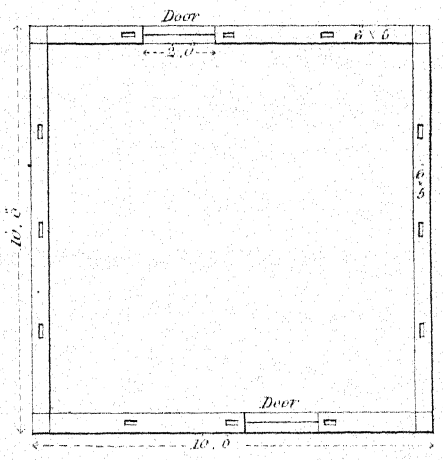
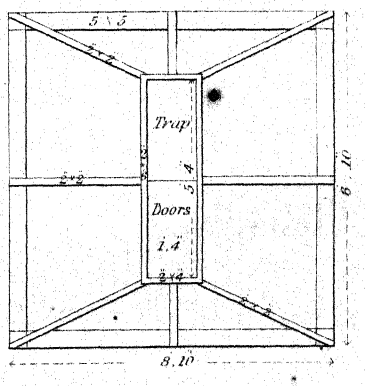


Fig. 13.

TOP FRAME & RAFTERS.



J.W.Lowry fc.

London. John Weale. High Holborn 1849.

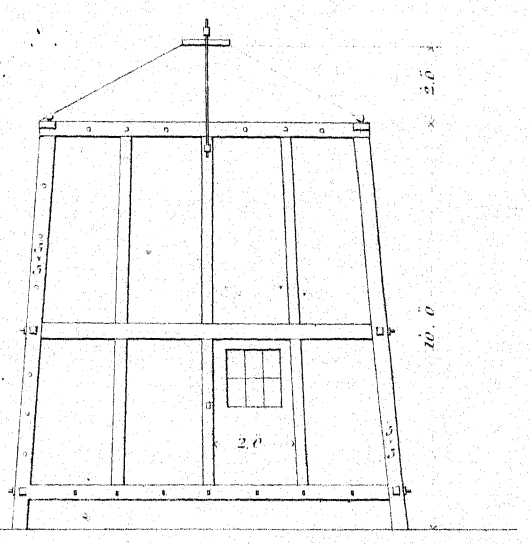


PORTABLE OBSERVATORY.

North and South Sides of Zenith Sector.

ELEVATION.

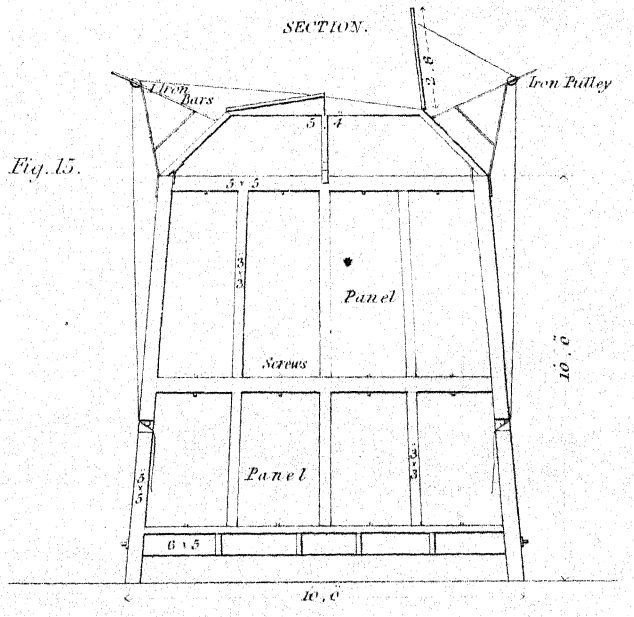
Fig. 14.



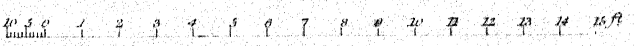
North and South of Zenith Sector.

SECTION.

Fig. 15.



Scale of Feet



J. W. Lowry. fo.

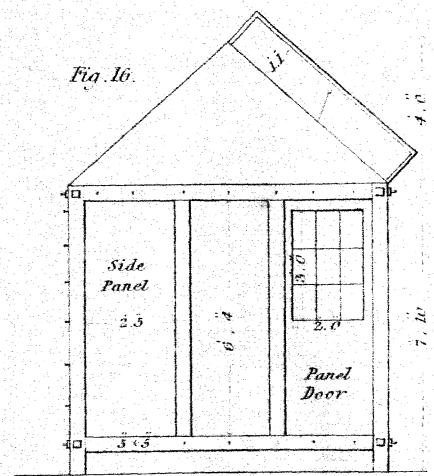
London. John Weale. High Holborn. 1849.

PORTABLE OBSERVATORY FOR A TRANSIT INSTRUMENT.

END ELEVATION

Roof Door Raised

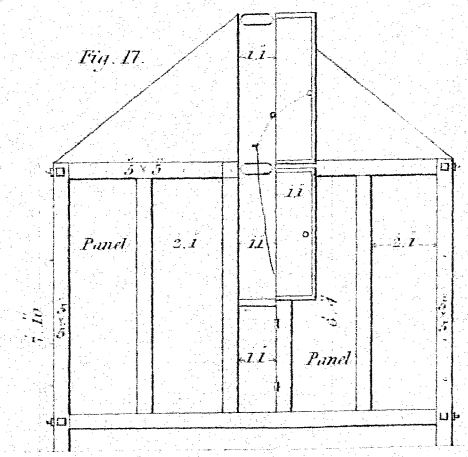
Fig. 16.



ELEVATION OF NORTH AND SOUTH

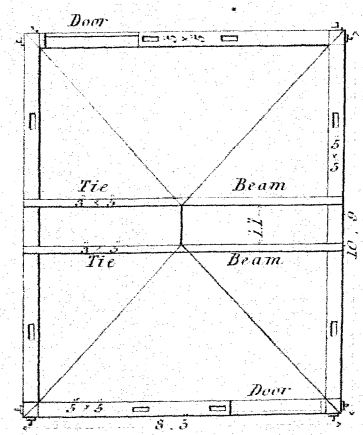
with Roof Door & Side Door open.

Fig. 17.



PLAN

Fig. 18.



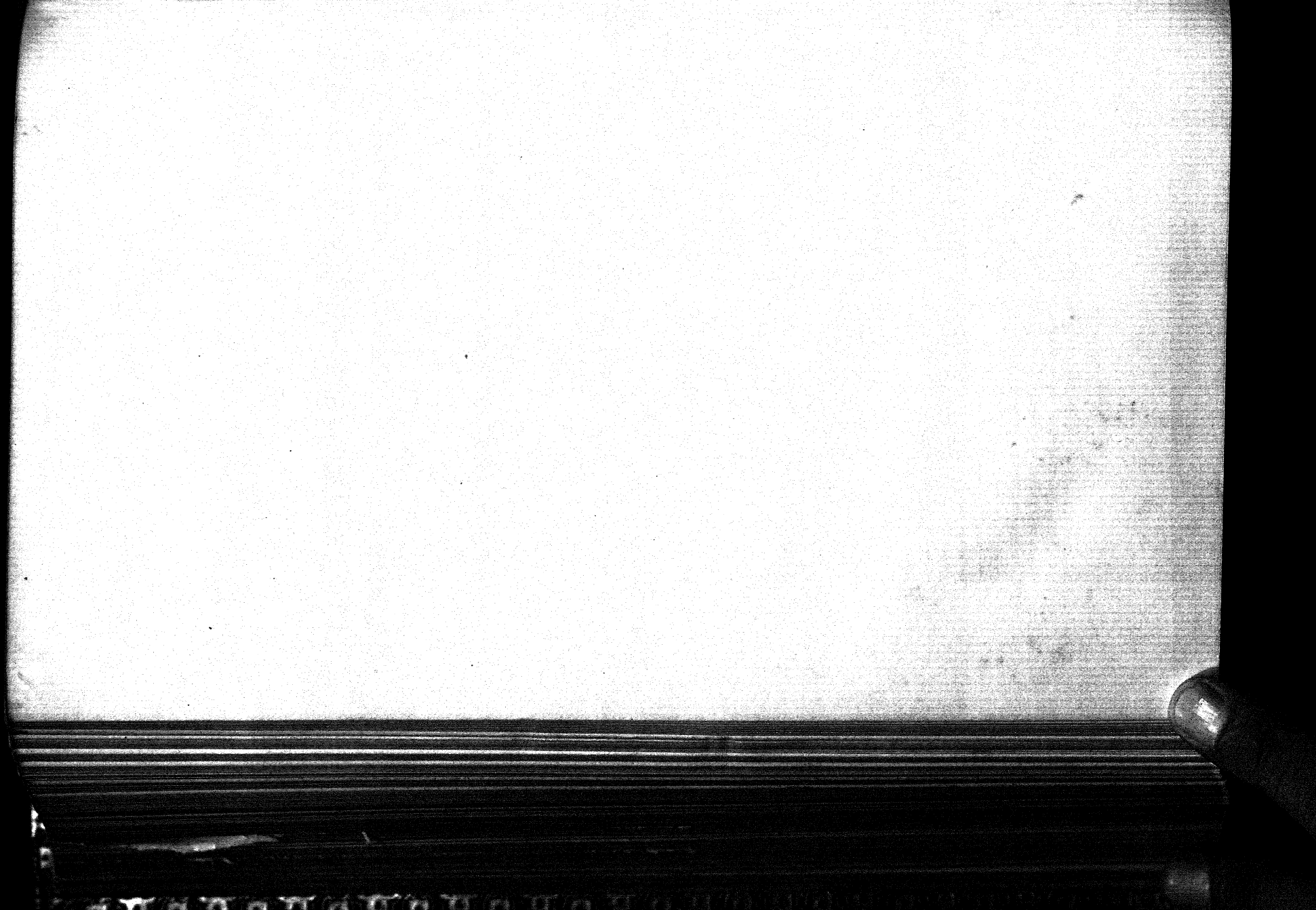
Scale of Feet

10 5 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 ft

London, John Weale, High Holborn, 1849.

T.W. Lowry, Sc.

OBSERVATORY ASTRONOMICAL. PLATE 14.



irregular fluctuations and regular secular changes are governed, as well as their connection with meteorological phenomena, besides other purposes which need not be here more alluded to, a laborious and continued system of observation was necessary to be made at geographical positions selected chiefly for magnetical considerations; and accordingly a certain number of observatories were established at
Plates III. & IV. stations of primary importance. The British Government undertook the cost of four of these observatories in different parts of our colonial possessions, viz. Canada, St. Helena, the Cape of Good Hope, and Van Diemen's Island; and the first three having been placed under the Ordnance department, a staff of observers for them was chosen from among the officers and non-commissioned officers of the Royal Artillery: the observatory at Van Diemen's Island was intrusted to the care of officers of the Royal Navy.

We may now proceed to give a brief account of the instruments with which these observatories were supplied, and of the instructions relative to the observations required to be made with them. As the observatories were furnished in all respects alike, and the system of observation was not only completely identical, but at simultaneous times, whatever may be related of one will apply with equal truth to the proceedings of all. The instruments used were,

Plates I.& II, 1. *A Declinometer*, for observing the regular daily, and irregular fluctuations, as well as for periodic changes.

This instrument consists of a magnet bar freely suspended by fibres of untwisted silk, and furnished either with a lens and scale attached to the magnet, or with a mirror reflecting the scale at a distance. A telescope directed through the lens to the scale, in the first instance, or to the mirror which reflects the scale, in the second, enables changes of very small amount to be at once noted.

2. *The Bifilar Magnetometer.*—As no method has yet been rendered practicable for observing in one operation the changes of the total intensity of the earth's force acting in the direction of the dip, the total force is resolved into two other forces, one acting in the horizontal plane and the other in the vertical plane. The bifilar magnetometer was designed for the purpose of measuring the changes of that part of the force which acts in the horizontal plane, and consists of a magnet bar kept at right angles to the magnetic meridian, suspended by a double thread of silver wire, passing round a grooved wheel at its lower extremity and between the threads of a screw at its upper extremity, the diameter of the wheel and the interval between the threads of the screw being accurately known, so that the two wires may be exactly equidistant throughout their whole length. Wheels of various sizes are supplied with each instrument, to be used as the station value of the horizontal force may require; it being necessary to employ a wheel of such dimensions that the torsion force caused by the twisting of the threads may exceed the magnetic force tending to draw the bar towards the meridian; yet not so much so as to impair the requisite sensibility of the instrument. The principle of the adjustment is briefly this. After having selected a wheel of suitable diameter, and suspended the magnet, turn the torsion circle any number of degrees (less than 180°) until the mean position of the magnet shall be exactly 90° from its original or natural position in the meridian. Now, were the suspended bar unmagnetic, the torsion circle would require to be turned only 90° to effect this object; but being magnetic, and having a constant tendency to return towards the magnetic meridian, the torsion circle requires to be moved more than 90°, and until the magnet assumes a position exactly at right angles to the magnetic meridian, in equilibrium between the force of torsion and the magnetic force. It is evident then, that supposing the magnetism of the bar itself to remain unvarying, an increase in the horizontal force of the earth's magnetism will be shewn by the magnetic force partially

overcoming the torsion force, and the bar approaching the magnetic meridian; or, on the other hand, a decrease in the horizontal force of the earth's magnetism by the torsion force overpowering the magnetic force, and the bar being drawn still more than 90° from its natural position.

3. The changes in the vertical component of the earth's magnetic force are observed by means of a *Balance*, or *Vertical Force Magnetometer*, the magnet resting on agate planes by knife edges which pass through its centre of gravity. Were the needle unmagnetised, it would become horizontal on the agates, being truly balanced on the knife edges passing through the centre; but being a magnetic needle, it assumes a position of its own—that of the line of the dip. The upper end is then weighted until the mechanical force overcomes the magnetic force, and the needle becomes horizontal. It is then in equilibrium between two forces, the magnetic force urging it into the line of the dip, but counterbalanced by the weight applied to the other extremity: then, the magnetism of the needle being supposed to remain constant (as in the instrument last described), an increase in the vertical force of the earth will be shewn by the tendency of the needle to approach the line of the dip, and a decrease of the vertical force by the weight more than counterbalancing the magnetic force, and the weighted end sinking below the horizontal line.

In the two last instruments it will have been remarked that the unchanging magnetism of the needle is essential to the correct determination of the earth's changes of force. Observations, as usually made, contain the changes of both mixed together, and it is necessary to eliminate the changes due to the varying magnetism of the bar before the true changes of the earth can be deduced.

Magnet bars are occasionally liable to undergo a gradual diminution of force; the effect of which it is necessary to take into account where a series of observations extending over a lengthened period of time requires to be reduced; but for short intervals, as from hour to hour, or day to day, the magnetism of the needle may be supposed stationary from this cause, and no correction applied. But there is another cause of change in the bar's magnetism, which on no account can be neglected,—that arising from a variation in the temperature of the metal since the previous observation was made.

The amount by which the magnetism of a needle varies by a change of temperature is not the same for all, but must be determined by experiment for every separate magnet; the process of experiment being simply this. The magnet whose *co-efficient of temperature* is to be determined is placed in a trough, and made to deflect another magnet freely suspended; water of various temperatures is poured into the trough, and the amount of deflection at each temperature noted. There will then have been observed a certain change in the effect produced upon the suspended magnet for a certain change in the temperature of the magnet under examination; from which data, by a simple process of calculation, the co-efficient of the magnet is obtained.

4. Since the first establishment of the Ordnance Magnetical Observatories a new mode of determining the changes of the vertical component of the magnetic force has been devised by Dr. Lloyd, and is now generally employed, though not to the entire exclusion of the original instrument, the Balance Magnetometer, which in some instances has been quite successful. The principle of the balance magnetometer is unexceptionable in theory, but its construction requires an amount of mechanical skill rarely attained; the accuracy of the results with some of the instruments of this kind has not consequently been as great as was expected, or indeed commensurate with that of the two magnetometers, for measuring the changes of declination and of horizontal intensity; the difficulty consisting in the very great proportion which the errors

introduced by imperfection of workmanship in the axle of the needle may bear to the whole magnetic force; and thus the most minute disturbance of the relative parts of the instrument, or the smallest irregularities in the bearing points of the axle, affect the accuracy of the observations in a very appreciable manner. It was therefore desirable that some mode for observing the vertical component should be employed, which should not involve the principles of the balance. Dr. Lloyd devised an instrument for this purpose, which he called the *Induction Inclinometer:* it consists of a magnet suspended horizontally, acted upon by one or more soft iron bars held vertically in its vicinity. The iron bars should be, as nearly as can be obtained, devoid of permanent magnetic polarity: when held vertically, they will become temporary magnets under the inducing action of the earth, the lower extremities (in stations of northern dip) being north poles, and the upper extremities south poles: accordingly, if one be placed upon each side of the suspended magnet, and adjusted in such a manner that the horizontal plane passing through the centre of the magnet shall likewise pass through the upper end of one iron bar and the lower end of the other, the magnet will be acted upon by a north pole on one side and by a south pole on the other, and under their combined effect will be deflected a certain amount; the deflecting force being that of the vertical component of the earth acting by induction on the iron bars, while the opposing force is that of the horizontal component acting directly upon the magnet to bring it back into the magnetic meridian. Thus the magnet will take up a position of equilibrium between these two forces, and a movement from its mean position, from which the effect due to any changes of horizontal intensity has been eliminated, will be that which is due to the change of the vertical intensity of the earth's magnetic force. A variation of temperature has a slight effect upon the induced magnetism of these soft iron bars, but in a much smaller degree than upon the permanent magnetism of hardened steel magnets. The co-efficient of temperature for the bars of each instrument must, however, be experimentally determined, the process being conducted in the following manner.

Surround the iron bars with water-tight cylindrical cases, made of wood or copper, soldered on to the arms which hold the bars, in such a way that they appear in the centre of each case, with space enough around them to enable the cases to contain a sufficient quantity of water to preserve an equable moderate temperature for a short time.

Adjust the instrument as for observation in the usual manner; fill both cylinders, first with warm water and then with cold; the two temperatures being the extremes to which the bars may be liable when required for observation.

At each alternation note the reading of the magnet scale and of the thermometer, when it will be found that the change of a certain number of degrees of temperature of the bars produces a certain amount of change in the magnetometer reading.

The induction inclinometer concludes the list of *differential* magnetical instruments required for the equipment of an observatory: their use, as will have have been remarked, is that of shewing continuously the *changes* which occur in each element. Instruments of a different description are necessary for determining the *absolute* values of the same elements.

For the absolute declination, a magnetometer essentially unlike the differential apparatus is not required; as, supposing the magnet in the latter to be provided with an attached lens and scale, in the prolongation of which a theodolite is placed, the angle observed between the reading of the horizontal circle of the theodolite, when referred to the scale of the magnet and to a distant object whose bearing with the astronomical meridian is known, corrected for the difference between the *zero point* of the magnetic scale and the point at that moment on the vertical wire of the tele-

scope, will be the absolute declination. The *zero point* is the point of the scale corresponding to the magnetic axis of the needle, and is a mean of two readings found by observing the magnet, first in its direct or usual position, and secondly in that position inverted: provision is made for accomplishing this in the construction of the instrument.

The other absolute determinations required are those of the magnetic force and of the direction in which the force acts. No method has yet been devised for determining the absolute total force by one operation; the usual mode being to observe, 1st, the angle of inclination of the needle, or the direction of the force; and, 2ndly, its horizontal component: then the horizontal force, multiplied by the *secant* of the inclination, will be equal to the total force; or, multiplied by the tangent of the inclination, equal to the vertical force. At stations of high magnetic latitude a very small error in the determinations of the inclination will occasion great error in the deduced value of the total force, for the secants of angles of an amount approaching 90° increase in a very rapid ratio; so that in extreme cases this method of obtaining the total force becomes quite inapplicable.

Dr. Lloyd has lately suggested an instrument for determining the total force in high latitudes in which the angle of inclination is not included as an element of calculation, the relative accuracy of whose results increases indefinitely as the inclination of 90° is approached: this method is consequently to be preferred where the angle of inclination is of large amount; but in ordinary instances the total force will be better obtained by a determination of the horizontal component and of the inclination.

The *dip*, or angle of inclination is determined by means of an instrument called an *Inclinometer*, which consists of a divided circle fixed vertically upon a horizontal circle moveable upon the axis of the base: the needle, whose length equals the diameter of the vertical circle, is suspended upon two agate planes by axles which pass through the centre of gravity, and are perpendicular to the faces of the needle: the needle, when unmagnetised, will then, if truly balanced, traverse round the circle and remain in any position which may be desired. The mode of observation is as follows: the instrument being correctly levelled, magnetise the needle by passing two bar magnets, held one in each hand (the north pole of one and the south pole of the other downwards) over each face, beginning from the centre and drawing them over the ends; repeat this about ten times, and the needle will have acquired sufficient magnetism,—that end over which the north pole of the bar magnet was drawn having become a south pole, and *vice versâ*. Place the needle thus magnetised on the agate supports, and turn the horizontal circle until it hangs vertically; the face of the instrument will by this means be brought into the plane perpendicular to the magnetic meridian of the station. Having read the vernier of the horizontal circle, move it 90°, to bring the face of the instrument to coincide with the plane of the meridian; the position of the needle, when at rest, will then indicate the dip or inclination. As the vertical circle may not have been truly divided, it is necessary to observe the reading of the needle with the face of the instrument turned both to the east and west; and as the magnetic axis of the needle may not coincide with the axis of form, it is necessary to place the needle with each face alternately directed towards the observer. Lastly, as the centre of gravity may not coincide with the centre of motion, it is necessary to reverse the poles of the needle by magnetising it afresh, but making what has been hitherto a south pole the north pole, and the north a south pole: a mean of all the eight observations will be the inclination sought.

We now come to the determination of the *horizontal intensity*, the principle of which may be thus explained. If a magnetic needle be suspended horizontally, and allowed to vibrate, the square of the time of one oscillation, as compared with the

square of the time of the same, observed under similar circumstances at another station, is in the inverse proportion of the horizontal intensity of the first station to that of the second : it is manifest, then, that the relative proportion of the horizontal intensity at any number of stations may be obtained by vibrating the same needle at each. These observations are, however, *only* relative, and dependent upon the individual properties of the magnet itself; or, in other words, the result will be an expression in which the *horizontal force of the earth* is combined with the *magnetism of the needle.* If we then can ascertain the ratio that one of these bears to the other, we shall have two equations in which each is an unknown quantity capable of elimination, and consequently the horizontal force of the earth may be determined in absolute measure. The ratio just spoken of is found by using the magnet employed in the vibrations, to deflect a second magnet suspended in another magnetometer, and observing the amount of deflection produced ; then, one-half of the cube of the distance at which the centre of the deflecting magnet is placed, multiplied by the sine * of the angle of deflection, is to unity, as the magnetic moment of the deflecting magnet is to the horizontal force of the earth ; which is the ratio required. By the experiments of vibration we obtain the product of the needle's magnetic moment and the horizontal intensity ; and by the experiments of the deflection we obtain the ratio of the same quantities, from which either may be eliminated separately.

By the employment of the instruments now mentioned, an observatory will be fully equipped for determining each magnetic element in absolute measure, and for observing the periodic and secular changes over any space of time it may be wished to keep the instruments in use.

Besides these magnetical instruments, the colonial observatories were furnished with a complete set of Metereological Instruments, comprising Standard and Mountain Barometers, Standard, Wet and Dry, Solar and Terrestrial Radiation Thermometers, Hygrometers, Anemometers, and Rain-Gauges. The indications of these, as well as remarks upon the weather, are registered at stated periods, in conjunction with the magnetical observations.

We have already remarked the fact, that the direction of the magnetic force and its intensity vary as the observer changes his geographical position ; and also that these themselves, at any particular station, are liable to changes, whether secular, as from year to year, periodic, as depending upon the time of year or the hour of the day, or irregular, from extraneous causes known or unknown ; and, firstly, we proceed to notice the changes found in the magnetic elements by an observer altering his geographical position, or, in other words, the representation of the distribution of magnetism over the surface of the earth.

The distribution of the earth's magnetism is represented by means of maps or charts containing systems of curves drawn through all the points where the value of each element respectively is of equal amount : thus, a map of the magnetic declination will represent a series of curves drawn through all the points where the declination or variation is equal : these are called *isoconic* lines, or lines of equal declination. A map of the magnetic inclination will represent curves drawn through all the points where the inclination or dip is equal : these are called *isoclinal* lines, or lines of equal inclination. And, in like manner, a map of the magnetic intensity will represent curves drawn through all the points where the intensity is of equal amount : these are called *isodynamic* lines, or lines of equal intensity.

The magnetic direction, as has been already stated, must be resolved into two

* When the two magnets are placed at right angles *to each other*, the sines are employed ; but when the deflecting magnet is kept at right angles to the *meridian*, the tangents are taken.

elements,—the deviation from the astronomical meridian, measured on a horizontal plane, and the angle which the needle forms with the horizon, measured on a vertical plane.

The deviation from the astronomical meridian (latterly called the 'declination,' but more generally known as the 'variation of the compass,') is the element which, from its practical use, has naturally excited the greatest general attention. It is not necessary here to enter into the history of the discoveries of the properties of the magnetic needle: suffice it to say, that the knowledge that the needle did not point truly north,—secondly, that the deviation from the north was not the same in different localities,—and, thirdly, that the deviations, whatsoever they might be, were liable to continual change,—are all of recent date, compared with the discovery of the magnet itself.

The first attempt to form a variation chart was made by Alonzo de Santa Cruz, in 1530.* One hundred and fifty years later, Dr. Halley's theory of magnetism engaged so much attention, that a ship was granted him to seek by observation the variation of the compass in different parts of the world. He performed two voyages, one in 1698 and the other in 1699, and succeeded in obtaining so many valuable observations, that, on his return, he was enabled to construct a chart shewing the course of the curves of equal variation, 0°, 5°, 10°, &c. This work excited great interest, from being the result of personal observation; and it was the first that had yet been given to the world which could lay any claim to completeness or accuracy. It soon, however, became of little use for practical purposes, on account of the changes the declination was constantly undergoing; and half a century later, another chart was constructed from the records of various Naval Officers: this lasted until about the year 1787, when a chart constructed by Hansteen was published. Barlow published another in 1833. Since that apparently recent period, increased acquaintance with magnetism has suggested great improvements in the construction of instruments, which have been so actively employed in making observations, that the country is now in possession of ample data for the formation of correct magnetic charts of the greater part of the ocean. These, when completed, will bear a value much beyond any of those that have hitherto appeared, from being based upon direct observation alone, apart from theory, and with the employment of instruments incomparably superior to those of older construction, and also because the results have been calculated, having regard to certain corrections the importance of which has only recently become apparent, viz. such as arise from the effect of the ship's iron.

The great work of forming these magnetic charts has been commenced by the recent publication of Declination Charts of that portion of the globe covered by the Atlantic Ocean: these, together with an accompanying memoir, form the ninth number of Sabine's 'Contributions to Terrestrial Magnetism,' and are published in the 'Philosophical Transactions' of 1849. The curves are drawn for every degree of declination, upon the basis of the most recent observations, and are reduced to the epoch of January 1, 1840; a general table is added of the declination at the intersection of every 5th degree in latitude and longitude, from which may be calculated the value of the declination for any intermediate geographical position. In order to reduce the observation to any specified epoch, a second table contains the secular change per annum for each similar intersection in latitude and longitude, from which the correction is applied by simple addition or subtraction to the declination given for January, 1840.

It must not now be imagined that, with the possession of the charts and the tables for reducing the declination to a future epoch, this subject is disposed of, and will

* 'Cosmos,' vol. II. 282.

never require further consideration: such is far from being the case. In the first place, observations several times repeated in the same locality are necessary to determine the amount of the secular change, when constant; but it is well known that in many stations the secular change is not constant; and in such cases observations will require to be frequently repeated from time to time at these stations, to be used in the construction of new tables of the secular change per annum; and further, we have reason to hope that future observations will bear a higher intrinsic value than many that have been necessarily made use of in the charts now published: these observations, when made, will afford valuable verification of the normal values here employed.

A declination chart, however, includes but one element for a perfect representation of the magnetic phenomena: projections of the inclination and intensity are equally essential, together with tables by which we may be enabled to assign, with some degree of approximation, the values for either a former or future period. The completion of the Declination Charts of the Atlantic is one great step in contribution; but it is evident that there is still an extensive field for the labours of those interested in the knowledge of the laws of the distribution of terrestrial magnetism.

Of late years a thorough investigation into the laws of magnetism has been attempted, in which scientific men of all nations have employed themselves. The colonial observatories established by the British Government have already been alluded to: besides these, there are, in connection with Great Britain, a magnetical observatory at Greenwich, under the direction of the Astronomer Royal; one at Dublin, established and conducted at the expense of the University of Trinity college, under the superintendence of Professor Lloyd: and the Makerstown observatory at Kelso, in Scotland, supported at the private cost of General Sir Thomas Makdougall Brisbane, Bart.; the magnetic observatories at Madras, Singapore, Simla, and Trevandrum, at the expense of the East India Company; at St. Petersburg, Catherinenbourg, Barnaoul, Nertchinsk, Sitka, and Tiflis, supported by the Russian Government, which, ever alive in the cause of science, has also furnished the Russian mission at Pekin with magnetical instruments; observatories at Göttingen, Milan, Munich, Prague, &c.

In addition to the fixed observatories, expeditions, sometimes specially undertaken for magnetical observations, sometimes in conjunction with hydrographical surveys or exploring parties, chiefly commanded by officers of the British Navy, have been extended over almost every part of the globe, however remote or difficult of access. Some of these have returned, and the observations made by them have been published; some are still absent. Among the former class may be named the antarctic expedition of 1839—1843, under the command of Sir James Clark Ross; the expedition of Lieut. Moore, R.N., and Lieut. Clerk, R.A., in high southern latitudes, in 1845; Lieut. Moore, R.N., to Hudson's Bay, &c. Among the latter class must be reckoned the Arctic expedition under the late lamented Sir John Franklin, partially supplied by those sent after him.

From these sources our knowledge of the existing phenomena of the earth's magnetism may be expected to receive considerable increase, and possibly may lead to some elucidation of the physical causes which produce the phenomena, whether their origin be sought for in the mass of the earth itself, being the resulting action of all its magnetised particles, or, as has been conjectured, that the phenomena are due to electric causes on the earth's surface, produced by the sun, the "source of all living activity."

Though science has failed to throw any light upon the causes to which the magnetical phenomena owe their existence, observation has very generally borne out one at least of the theories proposed by the many philosophers who have made magnetism their study, respecting the laws of the distribution of the phenomena. It is to our

eminent countryman Halley that we owe the suggestion, first propounded in 1683, of the existence of four governing centres of magnetic intensity. So little credence appears, however, to have been given to this hypothesis, it is stated,* that up to "the commencement of the present century, the bare fact of there being any difference whatsoever in the intensity of the magnetic force at different parts of the earth's surface was unattested by a single published observation." Some years later, M. Hansteen undertook to examine the magnetical observations that had been made in regions of high latitude, and concluded "that Dr. Halley was the first person to discover the true magnetic arrangement of the globe, and that his deductions were fully as precise as the observations made in his time permitted." M. Hansteen proceeded to collect all the magnetic observations that had been made from the earliest periods. His tables extended to the year 1817; and after subjecting them to a close examination, he was enabled to prove the existence of a centre or focus of maximum intensity in the north of America; of a second centre, though not so powerful, in the north of Siberia; and of two corresponding foci, of unequal forces, in the southern hemisphere: he was also enabled to assign approximately the geographical position of each. That the data were insufficient for the more correct determinations of their positions, may be inferred from the remarkable fact, that at this time no observations had been made nearer the Siberian pole, than Berlin on the one side, and Mexico on the other.† Theory having thus pointed to the field requiring the labours of the experimentalist, subsequent observation has with some exactness shown not only the localities of these four foci or centres of intensity, but the relative numbers expressing at each the force of the magnetic attraction. The stronger focus of intensity in the northern hemisphere has been deduced, from observations made in 1843—1844, by Captain Lefroy, of the Royal Artillery, to be in 52° N. lat. and 92° W. long.; its value is 14·2: the weaker focus was determined by MM. Hansteen, Erman, and Due, to be in the north of Siberia, and about 120° E. long., with a value of 13·3. The stronger focus of intensity in the southern hemisphere is shown to be in lat. 60° 19′ and long. 131° 20′, from observations made by Sir James Clark Ross, during his late expedition in the southern seas, and to have an approximate value of 15·6; while observations during the same expedition render it probable that the value at the weaker focus is 14·9 nearly, the higher values in the southern hemisphere being probably owing to the fact that these foci are closer together than the two in the northern hemisphere; though observation is still wanting to enable their position to be assigned very accurately. Now, the position of the four centres of intensity being known, and the amount of the magnetic force at each determined, and considering the positions and forces as data from which the magnetic phenomena at other parts of the globe may be assigned, it is interesting to examine how far the theoretical phenomena calculated on this hypothesis accord with the general facts made known by observation.

In proceeding to notice the magnetic distribution, our attention was first directed to the phenomena of the declination. Let us, however, leave this element for a while, and consider in the first place the *intensity* of the forces: the reason for so doing will presently appear. If it be supposed that, instead of the magnetic foci occupying the positions above mentioned, they were exactly at the same distance apart, each from each, and that every one had an equal value; isodynamic lines, or lines of equal intensity, of less force, would form circles described about each focus as a centre, and decreasing in value until the systems of circles intersect, because the amount of the force exerted by any three of them would be the same at all points equidistant from the fourth: also, if there were but two centres, though of unequal degrees of force,

* Sabine on Magnetic Intensity. † Idem.

provided they were placed 180° apart measured on a great circle, the isodynamical lines described about each would still be circles. But as in reality there are *four* foci, all represented by unequal degrees of force, and at unequal distances from each other, the resulting action of the forces at any three centres causes the isodynamic lines to be found of the form of irregular curves about the fourth. As the centres in the southern hemisphere are probably at too great a distance to have more than a slight, if any, disturbing effect upon the curves in the vicinity of the centres in the northern hemisphere, and *vice versâ*, those curves should become ovals, having their longer axes directed towards the adjacent centre,—that centre alone practically exercising a disturbing influence in causing the curves to deviate from circles. By observation, such is actually found to be the case; the maps of isodynamic lines, drawn from observations distributed over a great part of the earth's surface, accord in all their leading features with those derived from theory; and there is little difficulty in conceiving that, the fact of the existence of four points or foci of maximum intensity being once established, and the position as well as the amount of the forces acting at each ascertained with some degree of certainty, the calculated isodynamic curves should coincide generally with the configuration of the curves found by actual observation.

It is evident that, starting from each focus of maximum intensity considered as a centre, the intensity is of smaller amount, in whatever direction we may proceed: if we then draw lines through all the points in which the intensity is equal, we form curves which are ovals surrounding each other, that which represents a less degree of intensity enclosing within it all those which are of greater amount: systems of curves are thus formed about four foci situated at certain positions on the globe. Continuing to draw these curves, the systems gradually approach each other, until at last two adjoining systems become actually in contact: the line then drawn through the points of equal intensity will represent the figure 8; and if we still continue to draw curves the two systems will become one, lines corresponding to lower intensities enclosing both centres. The systems that first come in contact are the two northern together and the two southern together; so that there are then but two systems, one about the northern foci and the other about the southern foci. Continuing still to draw curves, these two systems themselves eventually encounter, and when in contact, a more extended figure of 8 is formed.

We have now evidently reached the limit beyond which no closed curve of equal intensity round any of the centres can be drawn; but keeping in view that the curves are projected on the surface of a globe, we find that a space exists not traversed by any lines, and where the intensity is of smaller amount than we have yet noticed: this space opens in some localities to from 10° to 20° of latitude, and at one place contracts to a point, the point of junction of the northern and southern systems: commencing from this point of junction, and drawing a line through the minimum intensity on each geographical meridian, there will be formed a line *separating the governing forces of the northern foci from the governing forces of the southern*. This line "is not one of those which has been characterised or referred to by M. de Humboldt, but is an important one in the view which it enables us to take of the magnetical relations of the different portions of the globe:" * the intensity on this line is of unequal amount; at the point of junction the intensity is greatest, and at a point on the meridian where the northern and southern systems are the farthest distances apart, the intensity is least, and represents the minimum of force on the surface of the globe.

The forces acting at these foci govern likewise the phenomena of the magnetic

* 'Cosmos,' vol. i. p. 413, note by the editor.

declination and inclination, causing the *isogonic* and *isoclinal lines* to follow certain curves ; and it probably can be demonstrated that the calculated curves differ in no remarkable feature from such as are drawn from observation ; but it is a matter of much greater difficulty to comprehend the nature of the laws which produce these curves (the isogonic and isoclinal) than of the forces necessary to produce the isodynamic curves ; for this reason, that the isodynamic curves are purely magnetical, while the isogonic and isoclinal curves are expressed in reference to considerations having no necessary connection with magnetism. We cannot make this point more clear than by quoting at length the following remarks, extracted from Sabine's work on Magnetic Intensity.

"Viewed under the most favourable circumstances, and in its simplest aspect, the magnetism of the earth is still, it must be acknowledged, a highly complicated subject, and needs not the additional complication of its phenomena being involved with considerations foreign to itself. Now the lines of equal dip and equal variation do not express simple magnetic relations. The lines of equal dip, for example, connect those stations on the earth's surface where the direction of the magnetic attraction forms a certain angle with the horizontal plane at the station. But every station has its own horizontal plane, depending on the *direction of gravity*, which has no known or necessary connection with magnetism. The zero planes thus differing, the equality of dip does not express or necessarily imply a simple magnetic relation, but has reference to the attraction of gravitation, as well as to that of magnetism. The lines of equal variation express a complex relation of a similar character. Here, also, the zero planes change with the station ; and, the variation being the same at two stations, by no means implies parallelism in the direction of the needle at them, or any other specific relation whatsoever, independent of the geographical pole, which pole has no known or necessary connection with magnetism. It is not the same with the lines of equal intensity. Whatever may be the sources of magnetic attraction, and wherever their situation in space,—whether superficial, as regards the earth, or above or beneath its surface,—the line of equal intensity expresses the equality of their resultant at all those points of the earth's surface through which it is drawn, unmixed with any considerations foreign to magnetism. They are pure magnetical isodynamic lines at the surface of the globe, and express a common relationship to the sources of magnetical attraction. The instruction they convey is therefore more simple, direct, and unequivocal than in the case of the other two. The eye of the mathematician may discern the pure magnetic indication through the complex signification of the lines of equal variation and dip ; but the lines of intensity are better suited to convey the system of magnetism as indicated by the phenomena to the general apprehension."

The course of the *isogonic* lines presents some prominent features, the most remarkable of which are their general convergence towards the centres of maximum intensity in the northern and southern hemispheres ; within a short distance of these points will therefore be found variations of great amount, both in the easterly and westerly directions.

The course of a line on which there is no variation is found to traverse the space between the two northern centres where the tendency of the magnetic needle to the eastward, under the influence of one centre, is exactly counterbalanced by the tendency of the needle to the westward, under the influence of the other. A similar line, along the whole of which there is no variation, is found between the two southern centres, following a course where the needle is in like manner governed by the influence of one southern centre exactly counterbalancing the influence of the other. But perhaps the feature most capable of arresting attention in examining

a chart of variation, is the existence of two ovals or curves of equal declination whose extremities meet and form closed systems: one of them is situated in the Pacific Ocean, and the other in Eastern Asia.

The general aspect of the projection of the *isoclinal* curves conveys the impression of a greater simplicity in the action of the forces by which they are produced, than in the forces which govern the isogonic and isodynamic curves.

The line of no dip, or the line drawn through all those points where the needle remains horizontal, and the inclination consequently equal to 0, encircles the globe near the terrestrial equator. From this line the inclination gradually increases as a higher latitude is attained, whether in proceeding northward or southward, until the vicinity of either pole be reached, when the needle becomes vertical, or the dip is 90°.

The above very brief description is sufficient to give a general idea of the course of the isoclinal lines, and is, in fact, but a very rough approximation to the truth, as we shall find upon entering into a more detailed examination of the question. It appears, from observations made by Captain Duperrey, of the French Navy,—who undertook a voyage of circumnavigation in the years 1822–1825, by order of his Government, for the purpose of making magnetical observations, and more particularly with the design of ascertaining the precise localities at which the needle remained horizontal, —that the line of no dip at that time crossed the equator in long. 5° E, (from Greenwich), and proceeding southward, attained its extreme southern limit in 15½° S. lat. and in long. 39° W.: turning from thence again towards the north, it reached within 2½° of the equator in 100° W. long., having on the way effected a slight retrograde movement near the western coast of South America: proceeding thence in almost a parallel line with the equator, but inclining slightly northward, it arrived in N. lat. in the meridian of 180°; continuing thence so rapidly to the northward, that it was found to have made 7½° of lat. in traversing 37° of long. eastward; and following the same parallel of latitude until the meridian of 120° was attained, northing was again gradually made, until the maximum distance from the equator of 13½° was reached, in 4° E. long. Turning from this point to the southward, the line proceeded uninterruptedly to its starting point on the equator, in 5° E. longitude.

If we start from the line of no dip, and travel directly northwards, the *north* end of the needle is found to incline below the horizontal line, and to dip more and more as we proceed: if we travel southwards from the same line, the *south* end of the needle becomes the lower, and continues to incline in like manner in our progress; but the increase of the angle of inclination, in low latitudes especially, more than keeps pace with the increase of the latitude. Humboldt, on one occasion, found a change of inclination, amounting to 8° 1′, corresponding to a difference of 3° 57′ of lat.; and upon another, a change of inclination of 20° 7′, produced by a difference of 9° 50′ of latitude. While such is the case, a ship's position may often be known from a determination of the inclination, when an astronomical observation could not be obtained; in fact, the magnetical observation might often be found not only the most simple, but the most useful, from its results being available at any time of the day or night. Instances are on record where the magnetical observation has actually been applied to this purpose.

Sir J. C. Ross observed the needle to be vertical, the north end dipping 90°, on the 2nd June, 1831, in lat. 70° 5′ N., long. 96° 46′ W.* The same Officer observed a south inclination of 87° 5′ in lat. 74° 59′ S. and long. 173° 40′ E., the greatest

* 'Philosophical Transactions,' Part I. for 1834.

inclination of the south end of the needle that as yet been observed. From his observation it has been inferred that the needle would be vertical in about 74° S. lat. and 150° E. longitude.

It has occurred to us here to remark, for the purpose of preventing the possibility of mistake, that wherever in this paper the North end or pole of the magnet is spoken of, it is to be understood that we refer to that end which points towards the North, and of the South end that which points towards the South. It is necessary that a clear understanding on this point should exist, because many writers employ these terms precisely reversed, calling the North end of the needle that end which is directed towards the South, and *vice versâ*, stating as a reason, that because the north pole of a magnet repels the north pole and attracts the south pole of another, that is, as there exists a repulsion between powers of the same name, and attraction between powers of the opposite name, they consider that the earth, the most powerful of all magnets, should be supposed to exert a similar effect upon magnets influenced by it, and therefore that end of the needle attracted towards the North pole of the earth should be called the *South* end, and that end repelled from the North pole and attracted towards the South pole, should be called the *North* end of the needle. We have, however, employed the terms most generally in use, as more obvious and less likely to cause confusion.

Having now completed a general view of the distribution of magnetic elements over the globe, we may proceed to notice the changes to which these elements are liable.

The secular change is that change by which an element at any particular station is found to increase or diminish from year to year, sometimes reaching a certain limit, and then slowly returning to the original value. This, no doubt, is due to the movement of the governing centres of intensity; but the direction and rate of that motion, and whether all or any of them make the circuit of the globe, are questions not yet capable of correct solution. The effect of the secular change is, in the course of a series of years, so to alter the earth's magnetic distribution, that the existing maps exhibiting graphically the course of the curves no longer convey correct representations of this phenomena, and consequently render it necessary to resort to observation again for the construction of new maps. For this purpose, Humboldt says, "it would be requisite to send, four times in each century, an expedition of three ships, which should have to examine, as nearly as possible at the same time, the state of magnetism over all the accessible parts of the globe which are covered by the ocean."

The next order of changes are the regular diurnal fluctuations.

Mr. Graham, a celebrated mathematical instrument-maker in London, is said to have discovered, in 1722, that the northern extremity of the needle moved westward during the early part of the day, and returned again eastward in the evening to the same position which it occupied in the morning, remaining nearly stationary through the night.

The observations at the Colonial Magnetical Observatories having been made at the commencement of every hour throughout the twenty-four, the nature and amount of the diurnal movement at those stations has been determined with considerable accuracy; and it has been found, that not only the declination is effected by a regular diurnal march, but also that the magnetic intensity of the earth is subject to regular diurnal changes, as shewn by the variation of the magnet in the horizontal and vertical force magnetometers. The observations made at Toronto in Canada shew that at that station the north end of the needle attains its extreme westerly limit between 1 and 2 o'clock in the afternoon; that it moves to the eastward until between 9 and 10 at night, returning again westerly until about 2 A.M., from which time, until 8 A.M., it proceeds steadily eastward, when its limit is reached in that direction: from 8 A.M., until the early part of the afternoon, the progression is rapidly and

steadily westward. The same observations shew that these movements are somewhat modified by the season of the year; that during the summer months the extreme limits take place rather later, both in morning and afternoon, and that the range is considerably greater; the amount of the diurnal variation being from 10′ to 12′ during the summer months, and not more than from 5′ to 7′ during the winter months; the movement in the spring and autumn bearing an intermediate character.

The curve of daily variation will probably be found to possess the same general character at all stations in the middle latitudes of the northern hemisphere. The Greenwich observations, taken two-hourly, shew that the western limit is attained extremely regularly at 2 P.M., but that the eastern limit is more generally found at the hour at which the second minimum is reached at Toronto, viz. about 10 P.M.; though frequently, and more particularly during the summer months, the extreme eastern limit is attained at the morning hour, 8 A.M. The Greenwich observations also exhibit the double movement, having two maxima and two minima.

In the middle latitudes of the southern hemisphere, the hours of local time corresponding to each turning point seem to be as nearly as possible identical with the turning points in the northern hemisphere; that is, comparing the daily movements of a declination magnet situated in the northern hemisphere with the daily movements of another magnet at a station in nearly similar latitude in the southern hemisphere, and situated on the same meridian, there is found to be a remarkable connection between the movements of the two magnets, the extreme positions and the secondary maxima and minima being attained at nearly simultaneous times; but the directions of the movements are precisely contrary: while the north end of the magnet is progressing westwardly in the northern hemisphere, the north end is moving eastwardly in the southern hemisphere, and *vice versâ*. The peculiar connection between the diurnal curves in the northern and southern hemispheres is further exemplified in the effect of season: the characteristic feature of the summer curve in the northern hemisphere, as has been already stated, is that the diurnal changes are much greater than in the winter months; and this we find to be the case in the southern hemisphere, the greater diurnal movement taking place during the southern summer months.

If we consider the contrariety of movements simultaneously occurring in the northern and southern hemispheres, we perceive it to be clearly impossible that two observers approaching the equator in opposite directions should find that the western movement of the north end of the needle is suddenly converted into an eastern movement, and an eastern into a western movement, and that therefore the conjecture was by no means unreasonable, that as the observers approach each other, the diurnal changes would be found gradually to diminish, both ceasing altogether in a space or zone where, the two movements being neutralised, the needle remained stationary. M. Arago arrived at this conclusion, expressed in the following words: "il y a nécessairement entre la zone où s'observe le premier de ces mouvements et celle où s'opère le second, une ligne où, le matin, l'aiguille ne march ni à l'orient ni à l'occident, c'est-à-dire reste stationnaire." Humboldt recently alludes to the same problem, and appears to consider the existence of a zone or line round the earth, answering these conditions highly probable. The question has, however, been solved, and in a manner, perhaps, scarcely anticipated.

Sabine has shewn, in a paper read before the Royal Society, February 18, 1847,* that there are certain stations, which may be regarded as situated between the northern and southern magnetic hemispheres, where the diurnal variation possesses the characteristics of the phenomena of both. While the sun is in the northern

* 'Philosophical Transactions,' Part I. for 1847.

signs, the movement of the north end of the needle corresponds in direction to what we have mentioned as taking place in northern latitudes; and while the sun is in the southern signs, as to what we have mentioned as occurring in southern latitudes. This conclusion was arrived at from the examination of the results of the observations at the Observatory at St. Helena, situated in 15° 57′ S. latitude, and where the inclination is about 22°. The fact is very decidedly proved, that in November, December, January, and February, the diurnal variation corresponds to that observed at Toronto in Canada, as an instance of the diurnal variation in the northern magnetic hemisphere, while in May, June, July, and August, the variation is similar to that observed at Hobart Town, Van Diemen's Island, considered as exemplifying the diurnal variation in the southern magnetic hemisphere; also, that in March and April, September, and October, the months when the sun is in the vicinity of the equator, the movements partake more or less of the characteristics of both seasons: a detailed examination of this subject will be found in the paper already alluded to, and we without hesitation arrive at the conclusion that a line or zone characterised by the disappearance of all diurnal variation does not exist on the globe.

This interesting peculiarity in the diurnal curve of the declination, as well as the general employment of the instrument for practical purposes, has induced us to refer particularly to its changes. It may be sufficient to notice, with respect to the indications of the other instruments, that the force undergoes a certain change depending upon the hour of the day, forming each day a certain curve in an extremely regular manner; and we dismiss the consideration of these changes with the remark, which applies to all regular movements, that the occurrence of irregular changes are sufficient so frequently to destroy, or rather to mask the regular march of the needle, that a series of observations must be prolonged to some considerable extent, to arrive at any precise conclusions regarding the character of the curves. This has now been accomplished at the Colonial Observatories.

Our attention may next be directed to the irregular fluctuations, phenomena which are calculated to excite the greatest interest. These magnetic disturbances, when of any considerable amount, seem always to be accompanied by the Aurora, and both the disturbances and Aurora apparently to be excited by the same cause.

It has been the custom at the Ordnance Magnetical Observatories, upon an irregularity in the march of the needle manifesting itself, to commence continuous observations, and not to abandon them until the disturbances cease and the magnets return to the position due to the period of the day: as the regular observations are made hourly, the commencement of a disturbance can scarcely fail to attract immediate notice. Upon inspecting a table of disturbances, it is impossible to avoid at once perceiving that they appear to have been observed on the same date at several, or all of the stations, a great number of times. From such a list, now before us, it does not appear that a single disturbance of tolerable magnitude occurred at any one of the observatories, but that the magnets at all the others were observed to be in a similar state of perturbation; nor can the idea be resisted that the exciting cause, whatever it may be, is so general as to affect the magnetism at all parts of the globe at the same time. April 14th, 15th, and July 1st, 2nd, 3rd, and 4th, 1842; May 6th, 1843; April 16th, 17th, and October 20th, 1844, all days of much disturbance, taken almost at random from such a general table as that before mentioned, are instances of the exciting cause manifesting itself at stations widely scattered over the globe, and essentially unlike in geographical and climatological relations.

The interest that is attached to the phenomena of simultaneous disturbance, and the hope that a thorough investigation into their effects may conduce to some knowledge of causes, render it particularly desirable that no period attended with a dis-

turbance in the equilibrium of the magnetic forces should occur without an accompanying register of the needle's excursions.

So long as the establishment of an observatory is on a sufficiently extensive scale to permit a system of observation to be sustained, similar to such as has been in operation at the Colonial Observatories, a pretty constant watch can be kept upon the magnets, and any irregular fluctations scarcely fails to be noticed: the omission does not, at all events, extend beyond the hour at which the next regular observation is registered; and even that would be avoided, could an apparatus be contrived which should act as an alarum when the excursion of the magnet exceeded by a certain amount the usual diurnal variation; but when the disturbance has once commenced, unless a number of observers be ready to contribute their assistance, the movements of the magnets cannot be followed uninterruptedly; and should the disturbance extend over a period of many hours, the most zealous observers must in the end be compelled by fatigue to relinquish their task. For this class of observations, a mode of automatic registration would appear to be especially valuable; and as it is not advisable to impede in the slightest degree the free motion of the magnet, by causing it to exert any mechanical force, however slight, the desired object seems likely to be effected by means of photography. Mr. Charles Brooke is the inventor of an apparatus which has been employed with great success at the Magnetical Observatory at Greenwich, in self-registering the movements of the magnets.

The method consists in attaching to the centre of the magnet a concave elliptical mirror, which receives, from a camphine light, a vertical pencil of light passed through a slit about one-fourth of an inch deep and one-hundreth of an inch wide in the copper chimney of the lamp. The mirror reflects this pencil through a cylindrical lens, the axis of which is horizontal, thereby reducing the vertical pencil of light to a point, and the point of light is received upon prepared paper wrapped round a cylinder which revolves horizontally on its axis by means of clock-work. The point of light thus undergoes a horizontal movement corresponding to that of the magnet, but magnified proportionably as the distance of the cylinder from the mirror is increased; and the revolution of the cylinder causes each portion of the paper successively to be subject to the action of the point of light.

The chemical preparation of the paper, and the subsequent bringing out the curve traced, need not be here described. An account of the apparatus, illustrated by drawings, with fac-similes of some impressions obtained, is published in the 'Philosophical Transactions,' Part I. for 1847.*

An apparatus on a somewhat different principle, in which the use of the camphine lamp has never been found necessary, employing the sun's light by day and that of a common Argand lamp by night, is the beautiful invention of Mr. Francis Ronalds, of Kew. Mr. Ronalds's apparatus consists in suspending a very fine blackened wire vertically over or beyond the end of the magnet, passing through slits in the bottom of the case enclosing the magnet, and descending into a lucernal microscope beneath. Near to the wire, or index, as it is called, is the *object-end* of the microscope, closed by a pane of glass by day and by condensing lenses when the Argand lamp is used.

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* Since the above was written, Mr. Brooke has been able, by increasing the sensibility of the prepared paper, to cause a good impression to be produced by the action of naphthalized gas: gas is laid on at the Royal Observatory, Greenwich, which being passed through a vessel containing naphtha, is employed in the photographic registration of all the magnetometers. From still more recent experiments made at his house in London, Mr. Brooke entertains confident hope of so preparing the paper, that the action of a common oil lamp, notwithstanding the loss of light occasioned by reflection, may be sufficient to produce a distinct trace of the magnetic movements.

Between the index and the other end, fine achromatic lenses are placed, which have the effect of condensing the light upon a small screen fixed at that end, and also of projecting upon it a strong image of the index. A very narrow slit is cut horizontally in the screen, and behind it is a frame containing the photographic paper, which is enclosed between two thin plates of glass: the frame is moved in a vertical direction by clock-work. The clock being now started, every portion of the paper is carried successively past the slit, and exposed to the action of strong light; the index, however, interposes itself, and throws a shadow, reduced to a point by the horizontal slit, on the paper as it is drawn upwards. This shadow traces a curve, following exactly every movement of the magnet.

We have been desirous of limiting our notice of the important subject before us to a mere outline of its several branches, and of the modes of observation by which our knowledge of them continues to increase, and have endeavoured carefully to avoid being drawn into details, of which if each point received its due share we should have found the space allotted us in the present volume far from sufficient, as well as occasioning an inconsistency in the character of the publication. We are anxious, however, before concluding, to draw attention as briefly as possible to the study of magnetism chiefly in respect to the practical advantages attendant upon our increasing knowledge of the science, amounting to the supplying a hitherto much felt deficiency.

Many are disposed to regard magnetism in the light alone of an interesting study in abstract science; and though we are far from estimating the value of the study of pure science by its direct and visible bearing upon increased prosperity, believing it to be the never-failing means of exalting the intellect and purifying the mind, and that an adequate return for scientific researches is to be found in a higher standard of intellectual cultivation, yet the direct application of abstract investigation, though unperceived, is no less eventually certain; and we have evidence in the rapid advancement in manufactures and the arts, in our comforts and the every-day occurrences of life, of the practical application of purely scientific labours which in themselves were viewed as but profitless occupation, standing apart from worldly welfare, and interesting only to the speculative philosopher. But if we consider our subject in its practical and visible uses alone, we shall find proofs sufficient of the eminent real benefits to be attained by a more competent knowledge of magnetism. It is to the magnetic needle we are indebted for the safe guidance of our ships, as well in the ordinary navigation of the ocean as in the discovery of distant countries, ever the sailor's faithful friend, whether clouds and fog obscure the sun by day, or veil the stars by night. Yet our position with regard to the science may be truly described to be an imperfect knowledge of the magnetic distribution of the globe, or of the laws which govern its ever-varying phenomena, and a total ignorance of causes. Of late years much has been done to lay the basis, at all events, of a much augmented knowledge, and the subject has engrossed a degree of attention which it seems unaccountable to have delayed so long.

The principal practical use of the magnetic needle is, obviously, in the navigation of ships when out of sight of land; but that true dependence may be felt in its correct guidance, to enable known dangers to be avoided, and to inspire confidence that the ship is being truly steered to its destined port, we must not only possess a knowledge of the earth's magnetism, but we should take care to place in the hands of our seamen instruments really efficient, and above all, to secure the intelligent employment of them.

The compass, more perhaps than any thing else in the ship, is generally, as it ought to be, the object of the sailor's most jealous care; but it rarely happens that its construction is of such delicacy as is commensurate with the results expected from

its guidance, or that there is shewn sufficient acquaintance with its nature and properties; so that in fact the compass, in such cases, loses much of the value otherwise its due.

The cause which most frequently operates to impair the efficiency of the ship's compass, is the not ascertaining and allowing for the aggregate influence upon it of the ship's fixed iron, and from not observing due care in keeping moveable portions of iron-work from its vicinity. Several remarkable instances in which, owing to want of precautions of this kind, the most lamentable accidents resulted, are quoted by Captain Johnson, R. N., in a very useful book published lately, entitled 'Practical Illustrations of the Necessity for ascertaining the Deviation of the Compass.'

The comparative rudeness of construction of ship's compasses generally in use until within a very short period, and the before-mentioned causes rendering them in a still greater degree unsafe guides, were some time since urged upon the serious consideration of Government, and resulted in the appointment by the Admiralty of a Committee, who were directed to examine into the state of the compasses in the present employment of Her Majesty's Navy, and to suggest such improvements in their construction, and directions for their use, as would insure the proper application of a correct instrument to the purposes of Navigation.

The result of this inquiry has been, that in addition to the binnacle compasses, each ship of war is now ordered to be furnished with an instrument of very improved construction, called the 'Standard Compass,' and fixed upon a permanent support or pillar near the midship line of the ship, at a sufficient height above the deck to permit bearings being observed. Directions have also been given, that before going to sea, every ship shall be swung with her head successively upon each of the thirty-two points, and the deviation of the standard compass needle, or error from the magnetic north, caused by the iron of the ship, determined for each point; which deviation should be subsequently allowed for when laying down the course: these observations are to be repeated when the ship shall have changed considerably her geographical position. The ship's course is intended to be invariably directed by the Standard compass, and the corresponding bearing of the binnacle compass regarded solely as an approximate guide to the helmsman. Finally, an Observatory has been built, and placed under the control of Captain Johnson, whose duty it is to examine all compasses previously to being employed, to superintend the swinging of the ships, and to see that the Officers in charge possess correct tables of the deviations.

APPENDIX.

*Memorandum on the Books to be kept at the Magnetic Observatories.**

The books which will be required for registering the magnetic observations are—

1. A Day-Book.—2. A Term-Day Book.—3. A Miscellaneous Register.—4. An Abstract Book.—5. A Book for Curves.

1. THE DAY-BOOK.—The instruments required to be observed daily at the regular magnetic hours are, the three magnetometers, the thermometers of the horizontal and vertical force instruments, the barometer with its attached thermometer, the dry and wet bulb thermometers, and the electrometer, in all ten (10) in number: an observation with Daniell's hygrometer of the temperature of the dew-point will be taken four times daily, one at each of the magnetic hours nearest to the times 3 and 9 A.M. and P.M. of the reckoning in mean time at the observatory: the state of the

* From 'Report of Royal Society,' 1840.

weather will also be generally described at the same periods as are assigned for the observation of Daniell's hygrometer : at the magnetic hours this record is left to the discretion of the observer : *regular* observations at these times are not required. The maximum and minimum of temperature and radiation will be noted once daily.

Form No. 1 is arranged to contain a complete series of daily observations in one open page : the left hand contains the register of the magnetometers, and the right-hand page the meteorological register : the headings of the several columns in the Form have been entered, and will render them sufficiently intelligible without further explanation. Three readings of the declination and horizontal force instruments will be taken at each observation, and the horizontal lines corresponding to the times of observation have consequently been ruled in triple sets: the first and third readings of each observation should be entered on the left side of the columns so designated, and on the first and third lines of the set, and the second or middle reading on the right hand and on the centre line. In the vertical force instrument only two readings are taken at each observation, viz. one of each end of the magnet; they may be entered on the first and third lines of the set. The means of all the observations should be entered on the middle line of the three.

As the three magnetometers cannot be observed simultaneously by the same person, it is to be considered as a general rule that they are to be observed in the order and at the times following, viz.

Vertical force magnetometer, 2m. 30s. before the hour.

Declination magnetometer, at the hour.

Horizontal force magnetometer, 2m. 30s. after the hour.

As it is intended that the series of daily observations shall comprise the whole of one civil day, according to the usual reckoning of time at each observatory, it will be necessary to make the first set of observations at the time nearest after midnight, corresponding to one of the magnetic hours of Gottingen mean time : thus, supposing the difference of longitude, in time, of one of the observatories to be 4h. 36m. 41s. (or 4h. 37m.*) east of Gottingen, the time at the observatory of the first daily observation (*a* in Form No. 1) would be 12h. 37m. P.M., or thirty-seven minutes after midnight, and would correspond to the magnetic hour 8 P.M. of the day previous at Gottingen (A in the Form). The other observations of the magnetomers will follow in regular order, and will be fourteen (14) in number, including that one taken at 2 P.M. Gottingen mean time, which is triple. These instruments will be registered for the triple observation as follows :

H. M. S.	1	2	3	4	5	6	7	8	9
	1:50:00	1:52:30	1:55:00	1:57:30	2:00:00	2:02:30	2:05:00	2:07:30	2:10:00
	V	D	H	V	D	H	V	D	H

Numbers have been entered in Form No. 1, corresponding to those in the above Table, which will point out the time of observation for each instrument, and also the order in which they follow. This arrangement has been adopted in the Form, to prevent the necessity of leaving blanks.

* The nearest whole minute may be taken in the daily observations, but greater exactness will be necessary on term days.

The height of the barometer, and of its attached thermometer, of the dry and wet bulb thermometers, the temperature of the dew-point, the electrometer, and the state of the weather, will be entered in their proper columns on the right-hand page, at every magnetic hour, but not at the other times of the triple observations. The maximum and minimum of temperature and radiation may be noted at the foot of the right-hand page, after the state of the weather.

2. TERM-DAY BOOK.—One day in each month has been set apart for simultaneous observations of the three magnetometers, at short intervals. The declination instrument will be observed every five (5) minutes, beginning with each complete hour; and the horizontal and vertical force instruments every ten (10) minutes, each one successively in the middle of the alternate intervals, between the observations of the declination magnetometer; one observation will thus be taken every 2m. 30s., which makes twenty-four during each hour, or 576 during the day. The five thermometers, the barometer, the electrometer, and the state of the weather, will be registered at the beginning of each hour only.

The Term observations will be registered according to Form No. 2, in which each page contains the observations made during one hour. An inspection of the first page of the Form, in which the headings have been inserted, will render the mode of entry familiar.

The first observation will be made at 10 P.M., Gottingen mean time, of the Wednesday or Friday appointed, for which the corresponding time (to the nearest *second*) at the observatory must be calculated, and entered on the first set of lines of its proper hour-column. The time at observatory for each succeeding observation should be entered in a similar way, and the whole of the times for each complete term-day, twenty-four pages of the Form, should be filled up previous to the commencement of the observations, that no uncertainty may exist as to the precise time at the observatory at which each observation will have to be taken.* The three magnetometers will be registered successively, one under the other, on the lines corresponding to their several times of observation, as shewn in the specification column of the Form; these lines have been ruled in sets of three, for the same reason as given in the Day-book.

The hourly observations of the thermometers, the barometers, electrometer, and the weather, will be registered in their proper columns at the foot of each page, where will also be entered the temperature of the dew-point, at the four six-hourly periods, and the maximum and minimum of temperature and radiation.

3. MISCELLANEOUS REGISTER.—This book will contain the register of—

1. Absolute determinations;
2. Miscellaneous observations; and
3. Extraordinary observations.

The *absolute determinations*, which will be made *once every month*, are those of the dip, declination, and intensity of the earth's magnetism; the magnetic moment of the bars, and the fixity in position of the reading telescope.

Miscellaneous observations are those made for the adjustment of the magnetic and astronomical instruments; of the changes in the adjustments; of the effects of temperature on the magnets; of the latitude and longitude of the observatory (which should be occasionally repeated, until its place shall have been determined with all the

* It will be found advisable to have one of the chronometers set to Gottingen mean time, and if it have a *losing* rate it will be still more convenient, as the hands may then be moved *forward*, to the nearest minute of Gott. M. T. (an operation which does not affect its *rate*), whenever necessary.

accuracy which the instruments employed will admit of); for determining the time, and rating the chronometers, &c.

Extraordinary observations are such as will be taken whenever an indication may be made, by the movements of the magnetometers, that causes are in operation which exercise a disturbing influence upon the needle. Any remarkable phenomenon,—as an Aurora, for instance, which is known to exercise such influence, occurring during such disturbed movements,—should, if noticed, be carefully recorded.

The magnetometers are also to be watched during storms of thunder or wind, or during the occurrence of any phenomenon which may be suspected or considered likely to influence the movements of the magnetic needle, and their effect, if any, ascertained by a series of observations, and registered. Where no effect is observed, the same will, nevertheless, be noted, and a memorandum made of the time through which the magnetometers were watched, with reference to the phenomenon, to ascertain the fact. When, however, after several repeated observations during the occurrence of any, the same kind of phenomenon, as storms of wind, for instance, it shall appear that the magnets remain undisturbed, such observations may be discontinued.

The above observations will be kept separately for each month, and should be so arranged that an easy reference may be made, when necessary, to any individual entry.

No particular form is necessary for the miscellaneous register, but it will be convenient to have it ruled with faint lines, as in Form No. 6.

4. Abstract Book.—A monthly abstract of the observations taken each day will be made, according to Forms Nos. 3, 4, 5, and 6, and of the Term observations according to Forms Nos. 7, 8, 9, and 6. Each of the instruments registered daily, at the twelve magnetic hours, will occupy for the whole month one page of the abstract, and they will follow each other in the order of the Day-book, the thermometers attached to instruments being registered on the same open page with them.

The corrected observations of the barometer will be reduced to the temperature 32° Fahr., and corrected for capillarity; this latter correction, however, on account of the size of the tubes, is very small.

The temperature of the dew-point, and the elasticity of vapour corresponding to it, (which may be deduced from Table No. 5 in the Report), also the maximum and minimum of daily temperature and of solar and terrestrial radiation, and the monthly abstract of the daily triple observations, will be inserted in the three sets of columns ruled separately for each instrument; but the monthly means of these observations are not to be taken.

No observations are to be made on Sundays: the greatest number of working days, therefore, in one month, will not in any case exceed twenty-seven, for which extent the Form provides. The sums and means of the observations at each magnetic hour, for the whole month, will be entered in their proper hour-column at the foot of the page, on the horizontal line so designated.

All the observations taken on Term-days which correspond with the magnetic hours of the daily series, will be included in the abstract of the daily observations, as well as in the Term-day abstracts.

The monthly absolute determinations, as also the miscellaneous and extraordinary observations, do not require to be inserted after any particular Form; and a blank sheet of ruled paper will be added to the forms for each month, to insure space for their entry and for remarks.

The state of the weather as observed daily will admit only of being transcribed at length; it will be necessary to do this in the copies of the Monthly Abstract which are

to be sent home, but not in the Abstract Book which remains at the observatory, as they are registered in detail in the Day-book.

The Term-day observations will be abstracted agreeably to Forms Nos. 7, 8, 9, and 6, of which the first page is for the declination magnetometer, the second for the horizontal and vertical force instruments, page 3 for the hourly observations of the meteorological instruments, and page 4 for remarks.

The first page contains thirteen vertical columns, and is divided into two parts, each containing twelve horizontal lines: the first column is for the minutes of each hour in Gottingen mean time, at which the observations of the declination magnetometer are made, and the twelve following columns, which will contain the observations, are designated by the hours, in Gottingen mean time also, in order as they occur on the Term-Day Book. The upper half of the page contains the first twelve hours, and the lower half the last twelve hours of the twenty-four, commencing with 10 P.M. Gottingen M.T. of the day appointed in the programme. Each observation will be entered in the hour-column of that part of the page to which it belongs, and on the horizontal line designated by the minute of the hour which it was taken: thus an observation taken at the hour 6h. 45m. A.M. Gottingen M.T. would be entered in the *upper* part of the page on the 10th horizontal line, and in the 9th hour-column. Similarly an observation taken at 1h. 00m. P.M. would be entered on the 1st horizontal line and on the 4th hour-column of the *lower* part of the page: by this arrangement one column in each part of the page contains in abstract the observations of one page of the Term-Day Book.

The second page contains the abstract of both the horizontal and vertical force instruments, the observations of each of which are taken at double the interval of the declination instrument, *i.e.* every ten minutes; the former at 2m. 30s., 12m. 30s. &c., and the latter at 7m. 30s., 17m. 30s. &c., of each hour. The Form for both instruments is similar, and their designations differ only in the horizontal lines, which will be numbered as above in each Form, agreeably to the absolute times at which the observations of each instrument are made. The arrangement of the Forms is similar to that of the declination instrument, excepting that there are only six instead of twelve horizontal lines in each part for each instrument, corresponding with the number of observations per hour which will be taken, and that each part contains an extra line for abstracting the hourly observations of the thermometers of these instruments.

The method of entry is similar to that laid down for the declination magnetometer: the hourly observations of the thermometer will be entered on the horizontal line at the foot of each part, and in the hour-column to which it belongs, agreeably to the designation at the head of the part. One column of each part of these Forms contains, as above, the abstract of one page of the Term-Day Book.

The manner of abstracting and entering the meteorological instruments on Term-days will be sufficiently evident from an inspection of page 3 of the Form. The means of the observations will be taken every six hours, but their numbers being few, their sums will not be entered. The state of the weather at each magnetic hour will be transcribed into the unoccupied portion of the page in those copies of the abstract which are to be sent home, but need not be entered in the Abstract Book which will remain in the observatory, having been registered in detail in the Term-Day Book. The temperature of the dew-point, at the four six-hourly periods, also the maximum and minimum of temperature and radiation, will be entered likewise, in the vacant part of this page. The fourth and last page, which is for remarks, is ruled simply with faint lines, according to Form No. 6.

5. CURVE BOOK.—The comparison of the results will be much facilitated by pro-

jecting them in curves; and for this purpose each observatory is furnished with a Curve Book, the pages of which are printed from an engraved plate.

A comparison of *individual* results is only required where it is desired to trace the progress and laws of the *irregular* changes. Such a comparison, accordingly, will always be made of the results of simultaneous observations on Term-days. It may also be done when, on any extraordinary occasion, the progress of a disturbance has been watched at short intervals.

The mean results, contained in the Monthly Abstract, are,

1. The *daily means* of the results at the twelve *magnetic* hours, and
2. The *monthly means* corresponding to *each hour* separately:

the latter of these determine the laws of the diurnal oscillations, the former that of the monthly change. It is desirable that the monthly results of each of these series should be projected in curves; but it will be necessary, beforehand, to apply the corrections for temperature, as explained in the Report. The instruments whose results it is desirable to record in this manner are, the three magnetometers, the barometer, the wet and dry thermometer, and the electrometer.

The Form, of which a specimen is annexed, consists of twelve principal and two quarter compartments in length, and six principal and two half-compartments in breadth. Each compartment, which is an inch each way, is divided into six principal divisions marked by strong lines, and these are again subdivided into two by faint lines, so that the inch is subdivided into twelve parts each way. This arrangement has been made to admit of the more easy projection of Term-day curves, and because it is convenient in assigning the time value of the scale in the projection of curves generally.

The curves of the *monthly means* corresponding to *each magnetic hour* separately may be laid down on the breadth of the page, each half-compartment corresponding to the interval of the daily observations, or to *two hours;* each principal division, *i.e.* the interval between two strong lines, will represent one division of the scale in the declination and horizontal force instruments, the tenths of which will be *estimated* as they are in making the observations. For the vertical force magnetometer, one principal division of the Form will represent one division of the micrometer head, or five such divisions a whole turn of the screw. *Increasing easterly variation*, or an *increase of force*, will be represented by tracing the curve upwards, during the given intervals; and the converse for *decreasing* easterly variations, or for a *diminution* of force, *i.e.* by a descending curve. The point of commencement will be towards the *left*, and the intervals of time will be reckoned in regular succession to the *right*.

The *daily means* of the results at the twelve *magnetic hours* may be laid down across the page also, and in manner as above described, each principal division representing an interval of one day; increasing values being represented by an ascending, and decreasing ones by a descending curve.

The curves of the Term-day observations will be projected along the length of the Form, each half-inch representing an interval of one hour of civil time: one subdivision will thus be equal to ten minutes, *i.e.* to two intervals of observation of the declination, and one each of the horizontal and vertical force magnetometers; the values of the scale being taken as before directed. The curves will commence at the left hand, and be traced towards the right.

The curves of *irregular variations* will be laid down similarly with the above; but they may be projected on the breadth of the page.

The above books will form a complete record of the magnetic observations carried on at each observatory, and it would be desirable to have them collected in some one office, where access may be had alike to all, when the whole period through which they

are to be taken shall have expired. With a view, however, of comparing the results obtained at each observatory, and for the purpose of publication, duplicate copies of the monthly abstracts, both of the daily and term observations, and of the register of the weather, both on ordinary and on Term-days, will be required; and it is hoped that one copy, at least, of these documents will be despatched from the observatories regularly every month. Regarding the second copy, a particular arrangement will be entered into for their transmission, which will be communicated to the Superintendent of each observatory, for his information and guidance.

An Annual Report should also be furnished by the Superintendent of each observatory, noticing all occurrences which may appear worthy of special remark, giving a general history of the proceedings during the year, and stating the conclusions which, in his opinion, may be drawn from a comparison of the observations of one month with those of another. It will be interesting also to receive from each Officer, when the observatory under his superintendence shall be in regular course, a detail of the operations performed in making all the preliminary adjustments before commencing the series of observations with each instrument, and of the precautions taken to secure accuracy in their results.

FORMS OF THE BOOKS.

Note.—The letter *a*, at the head of the second column of Form No. 1, represents the time nearest after midnight, corresponding to some one of the magnetic hours of Gottingen mean time, and will always fall between midnight and 2 A.M. of mean time at the observatory. The letter *A*, on the same line in the first column, is that magnetic hour of Gott. M.T. with which *a* corresponds. The other letters in both series represent the consecutive magnetic hours, or intervals of two hours of civil time; the capitals in Gott. M.T. the small letters in M.T. at observatory. In the triple observations the letter H' represents 1h. 50m. P.M.; H stands for 2 P.M., and H'' for 2h. 10m. P.M. Gott. M.T.; and the letters h', h, and h'', represent the observatory times corresponding thereto.

The place of the triple observation will occur in different parts of the page at each observatory, according to the magnetic hour Gott. M.T., which may be there represented by the letter *A*. In the Form this is supposed to be midnight; *i. e.* the longitude of the observatory is assumed to be on the meridian of Gottingen, and, consequently, the times *A* and *a* are similar. The numbers 1, 2, 3, &c., inserted in the column '*Readings*,' shew the order in which the magnetometers are to be read, and represent also the *times* of those readings as contained in the columns of the Table, page 3, headed by similar figures.

The small letters in the first column of page 2, at the head of the twelve columns in Form No. 3, denote the same times as the like letters in the second column of page 1, Form No. 1.

All the Forms which relate to the observations of ordinary days, and their abstracts, have been printed in Italics; and those relating to Term-day observations, and their abstracts, in Roman type.

FORM No. I.

_____ *day, the* _____ *of* _____ 18____. } *OBSERVATORY at* (_____)
Daily Observations of MAGNETOMETERS.

Gott. mean time.	*Mean time at Observatory.*	*Declination Magnetometer.*		*Horizontal Force Magnetometer.*			*Vertical Force Magnetometer.*		
		Readings.	*Mean.*	*Readings.*	*Mean.*	*Ther.*	*Readings.*	*Mean.*	*Ther.*
A	*a*								
B	*b*								
C	*c*								
D	*d*								
E	*e*								
F	*f*								
G	*g*								
		2		3			1		
H′	*h′*								
		5		6			4		
H	*h*								
		8		9			7		
H″	*h″*								
I	*i*								
K	*k*								
L	*l*								
M	*m*								

Triple Observation.

* As the days commence with the magnetic hour nearest after 12 midnight *of the place*, the time of the triple observation will be different at each Observatory, and cannot therefore be printed.

FORM No. I.

OBSERVATORY at (_____) _____day, the _____of
and METEOROLOGICAL INSTRUMENTS. _____18____

Mean time at Observatory.	*Barometer.*		*Thermometer.*		*Electrometer.*		*Temp. Dew-Point.*	
	Height.	*Temp. of merc.*	*Dry.*	*Wet.*				
a								
b								
c								
d								
e								
f								
g								
h								
i								
k								
l								
m								

	State of the Weather.
a	*Note*
b	
c	
d	
e	
f	
g	
h	
i	
k	
l	
m	
9 *A.M.*	*Temperature Max.* ( ) *Min.* ( )
9 *A.M.*	*Radiation Sol.* ( ) *Terr.* ( )

FORM No. 2.

OBSERVATORY at (_____) _____ day, the _____ of
Term-day Observns. of MAGNETOMETERS, &c. _____ 18_____

Specification of Magnetometer.	Times of Observation.		Magnetometer.		Times of Observation.		Magnetometer.	
	Gott. M. T.	M.T. at Ob.	Readings.	Mean.	Gott. M.T.	M.T. at Ob.	Readings.	Mean.
	10 P.M. m. s.	m. s.			10 P.M. m. s.	m. s.		
Declination	0:00				30:00			
Horizontal Force	2:30				32:30			
Declination	5:00				35:00			
Vertical Force	7:30				37:30			
Declination	10:00				40:00			
Horizontal Force	12:30				42:30			
Declination	15:00				45:00			
Vertical Force	17:30				47:30			
Declination	20:00				50:00			
Horizontal Force	22:30				52:30			
Declination	25:00				55:00			
Vertical Force	27:30				57:30			

Hour of Gott. Mean Time.	Thermometers.				Barometer.		Electrometer.		
	H. F.	V. F.	Dry.	Wet.	Height.	Temper.			
10 P.M.									
	Weather.								

FORM No. 3.

OBSERVATORY at (_____)

*Abstract of daily Observations made during the month of*_____, 18____.

Date.	*Name of Instrument.*												*Sums.*
	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*	*m*	
Sums													
Means													

FORM No. 4.

OBSERVATORY at (_____)

Abstract of daily Observations made during the month of _____, 18____.

Date.	*Temperature of Dew-Point.*				*Elasticity of Vapour.*				*Temperature.*		*Radiation.*		*Moon's Age.*
	3 *A.M.*	9 *A.M.*	3 *P.M.*	9 *P.M.*	3 *A.M.*	9 *A.M.*	3 *P.M.*	9 *P.M.*	*Max.*	*Min.*	*Solar.*	*Terr.*	
Sums													
Means													

FORM No. 5.

OBSERVATORY at (_____)

Abstract of triple Observations made during the month of_____ 18____

Date.	*Vertical Force Magnetometer.*			*Declination Magnetometer.*			*Horizontal Force Magnetometer.*			
Sums.										
Means										

The Sums and Means of the triple observations are not required; they have been included in this Form, of which a portion is blank to admit of the insertion, if necessary, of other observations in the same page.

FORM No. 6.

FORM No. 7.

OBSERVATORY at (_____) _____ day, the _____ of }
Abstract of Term-day Observations _____ 18_____ }

Gott. Mean Time.	Declination Magnetometer.											
	10 P.M.	11	Midn.	1 A.M.	2	3	4	5	6	7	8	9 A.M.
m. s. 0:00												
5:00												
10:00												
15:00												
20:00												
25:00												
30:00												
35:00												
40:00												
45:00												
50:00												
55:00												

	10 A.M.	11	Noon	1 P.M.	2	3	4	5	6	7	8	9 P.M.
m. s. 0:00												
5:00												
10:00												
15:00												
20:00												
25:00												
30:00												
35:00												
40:00												
45:00												
50:00												
55:00												

FORM No. 8.

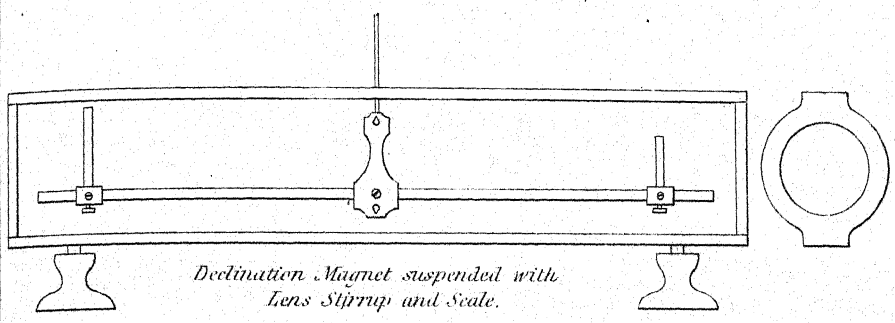
OBSERVATORY at (_____) _____ day, the _____ of }
Abstract of Term-day Observations _____ 18_____ }

Gott. Mean Time.	Horizontal Force Magnetometer.											
	10 P.M.	11	Midn.	1 A.M.	2	3	4	5	6	7	8	9 A.M.
m. s. 2:30												
12:30												
22:30												
32:30												
42:30												
52:30												
Ther.												

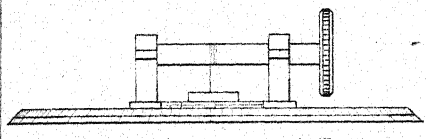
	10 A.M.	11	Noon	1 P.M.	2	3	4	5	6	7	8	9 P.M.
2:30												
12:30												
22:30												
32:30												
42:30												
52:30												
Ther.												

	Vertical Force Magnetometer.											
	10 P.M.	11	Midn.	1 A.M.	2	3	4	5	6	7	8	9 A.M.
7:30												
17:30												
27:30												
37:30												
47:30												
57:30												
Ther.												

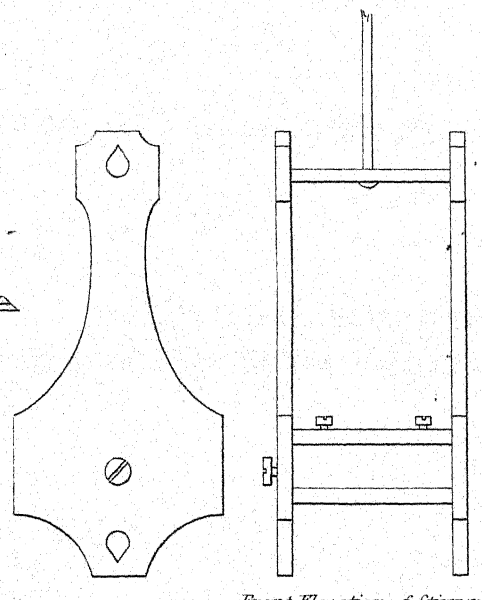
	10 A.M.	11	Noon	1 P.M.	2	3	4	5	6	7	8	9 P.M.
7:30												
17:30												
27:30												
37:30												
47:30												
57:30												
Ther.												



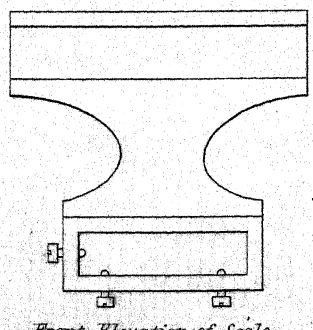
Declination Magnet suspended with Lens Stirrup and Scale.



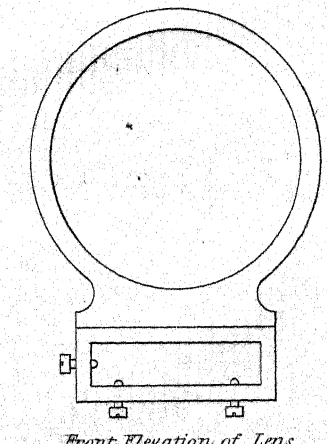
Suspension Apparatus and Torsion Cord of Declination Magnetometer



Front Elevation of Stirrup



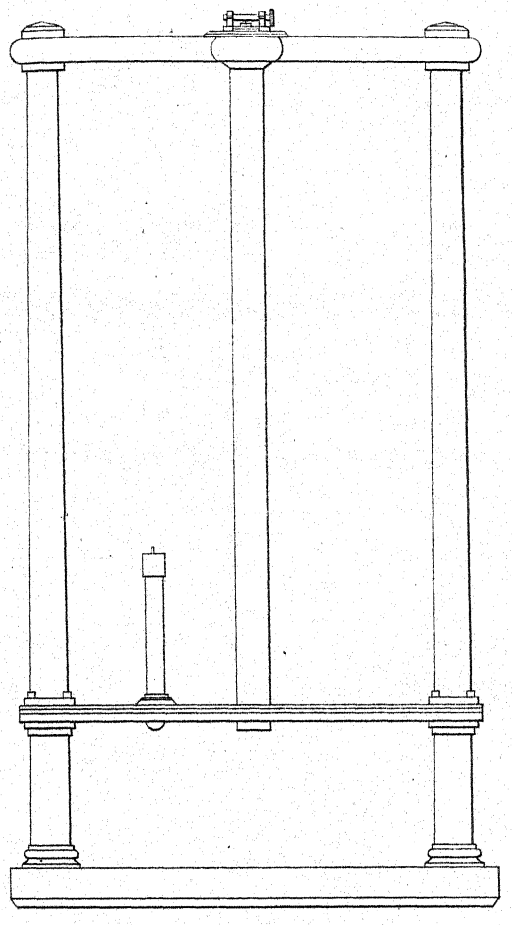
Front Elevation of Scale.



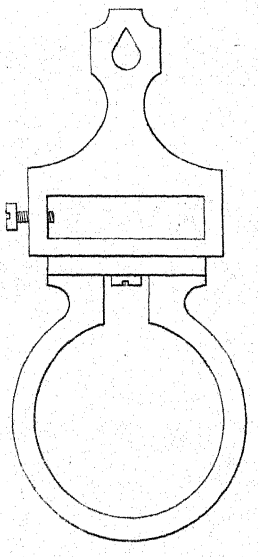
Front Elevation of Lens.

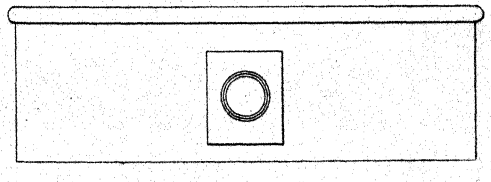
J.W. Lowry fe.

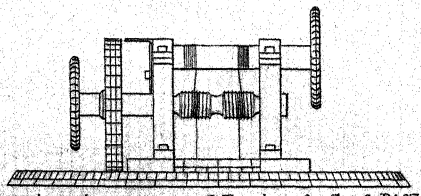
London, John Weale, 59 High Holborn, 1849.



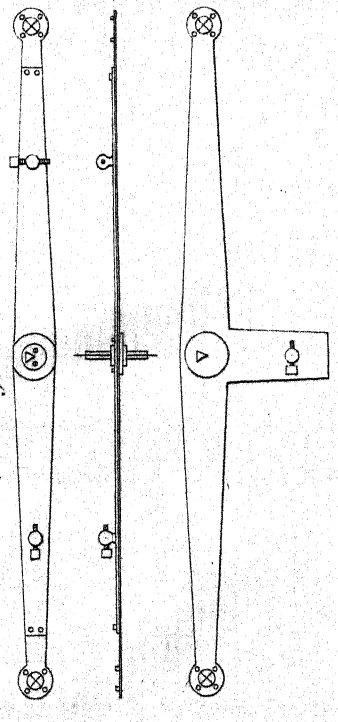
Frame work of Declination or Bifilar Magnetometer







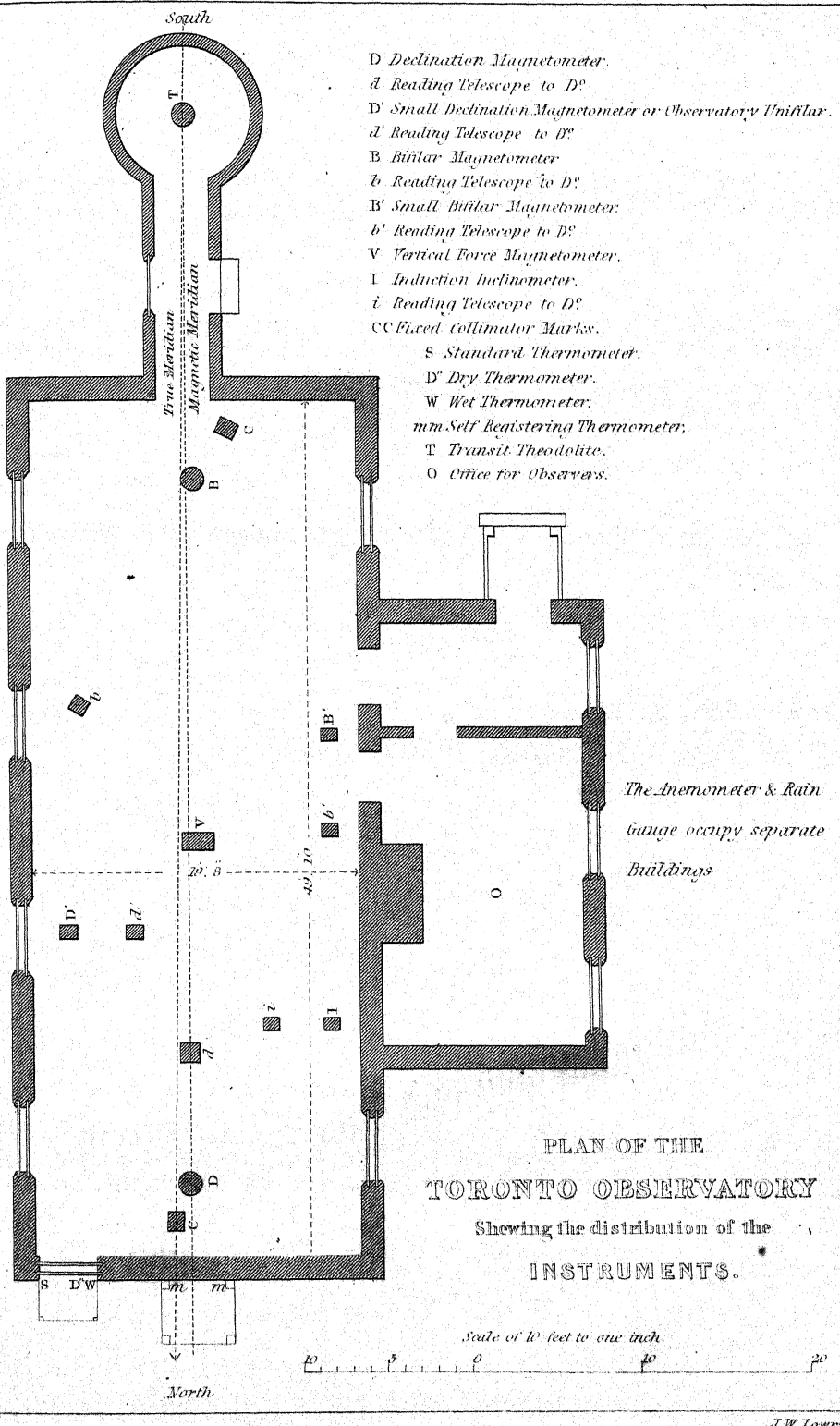
Suspension Apparatus and Torsion Cord of Bifilar Magnetometer.



Vertical force needle.

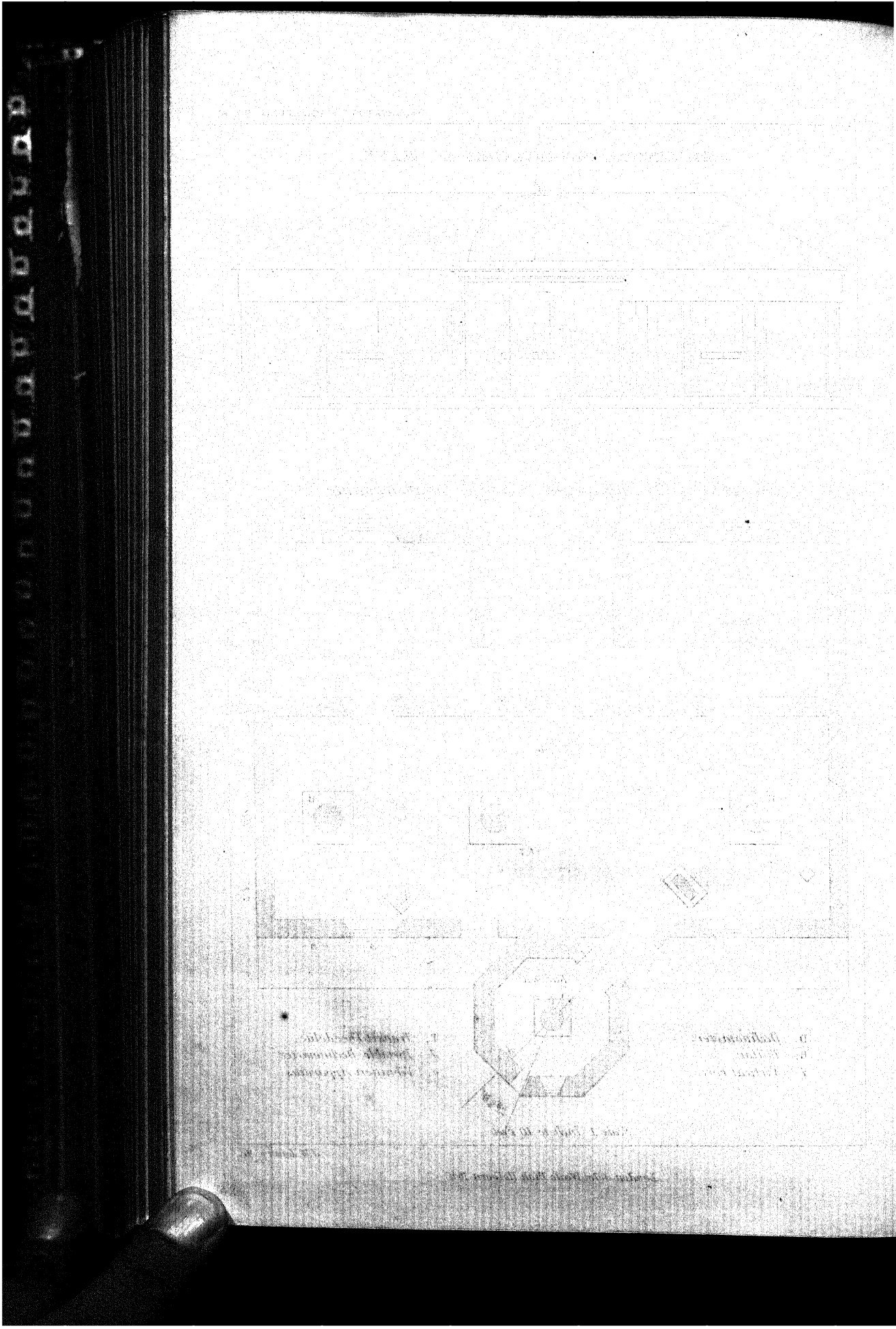
J.W. Lowry fc.

London, John Weale & Son Holborn 1849.

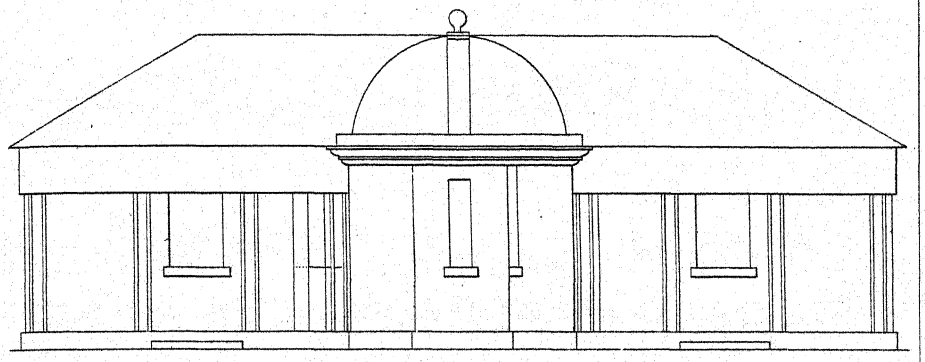


J.W. Lowry fc.

London, John Weale High Holborn 1850.

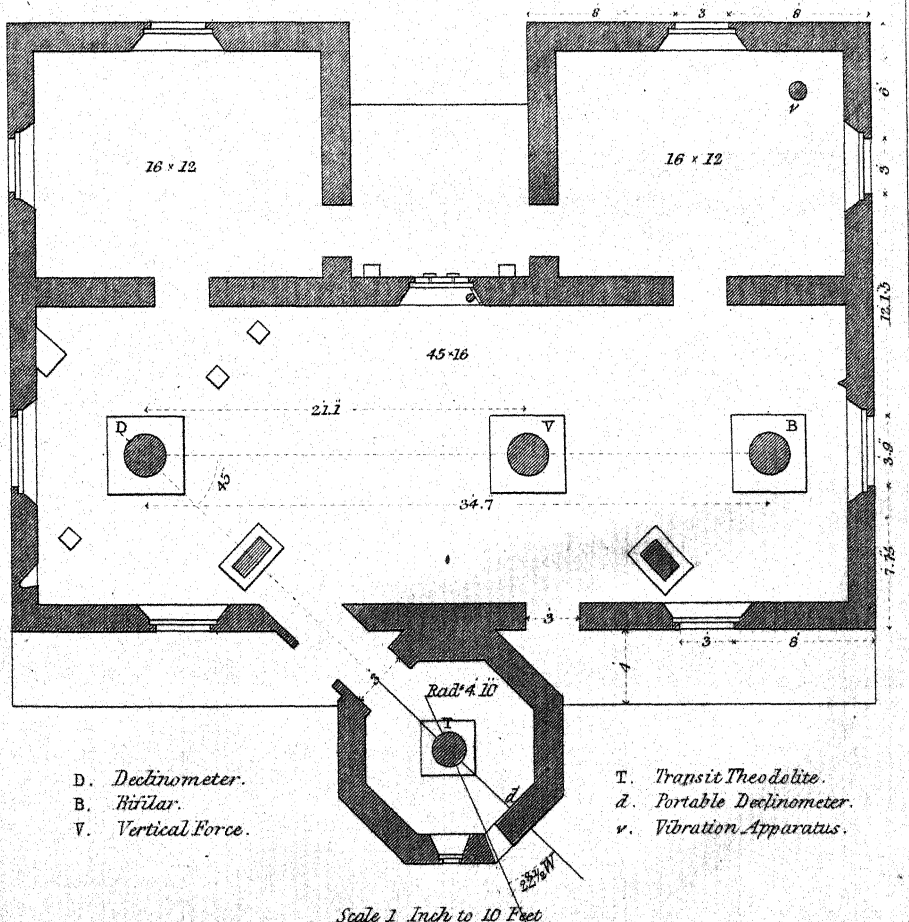


MAGNETICAL OBSERVATORY St HELENA.



ELEVATION

Ground Plan Shewing the disposition of the Instruments.



D. *Declinometer.*
B. *Bifilar.*
V. *Vertical Force.*

T. *Transit Theodolite.*
d. *Portable Declinometer.*
v. *Vibration Apparatus.*

Scale 1 Inch to 10 Feet

J.W.Lowry fc.

London John Weale High Holborn 1849.

FORM No. 9.

OBSERVATORY at (_____) _____ day, the _____ of }
Abstract of Term-day Observations _____ 18_____ }

Gott. Mean Time.	Barometer.		Thermometer.		Electrometer.		State of the Weather.
	Height.	Temp.	Dry.	Wet.			
10 P.M.							
11							
Midn.							
1 A.M.							
2							
3 A.M.							
Means							
4 A.M.							
5							
6							
7							
8							
9 A.M.							
Means							
10 A.M.							
11							
Noon							
1 P.M.							
2							
3 P.M.							
Means							
4 P.M.							
5							
6							
7							
8							
9 P.M.							
Means							

ORDNANCE, BRITISH.*—By the term Ordnance is understood, in the British Service, any description of warlike stores, whether for Land or Sea Service, and the Ordnance Department has the manufacture and conservation of these stores: this general application of the word is not the purport of the present article; it is its special signification as used by the Artillery, comprehending every projectile fired from a carriage and forming a part of the equipment of that branch of the Military Service; (as explained in the first volume of this work in the article '*Artillery*'). The nomenclature is as follows:

- Ordnance.
  - Iron
    - Guns,
    - Howitzers,
    - Mortars,
    - Carronades.
  - Brass.
    - Field Guns,
    - Do. Howitzers,
    - Small Mortars.
  - Rocket
    - Heavy,
    - Field.

The first use of ordnance, and the progress of the several improvements, are here proposed to be recorded.

It is supposed that ordnance, or a species of cannon, was first employed by the English in the reign of Edward the Third, and that in 1346 he had four pieces at the battle of Cressy: at that time they were made of wrought-iron bars, welded together and strengthened with hoops; but their construction rendered them more mortars than cannon, as they had chambers. One of this description, called 'Mons. Meg,' was taken by Oliver Cromwell at Edinburgh. Cannon of this material were also termed *Bombards*, but in time they were cast of that composition named gun-metal.

Although heavy ordnance were in use as early as the time of Edward III., none were cast in England until the reign of Henry VIII., when great brass ordnance were constructed, and called cannon and culverins, cast, according to Camden, by one John Owen: in the year 1543, the latter Sovereign employed two foreigners to assist in the foundry; and at the close of this century bombs were cast to fire carcases, fire-balls, and grenades.

At the beginning of the 17th century much attention was given to the casting of cannon in England, then designated as follows:

Cannon Royal,	carrying	48-lb.	shot,	of 90	cwt.
Bastard cannon	,,	36	,,	70	,,
Half ditto	,,	24	,,	60	,,
Culverins	,,	18	,,	50	,,
Demi-culverins	,,	9	,,	38	,,
Falcon	,,	6	,,	25	,,

Some curious notices of ordnance are given in a work printed in the year 1637, by Henry Hexham, Quarter-Master to the regiment of the Hon. Colonel Goring. He states that the charges of gunpowder were equal to $\frac{2}{3}$ths of the weight of the shot, and that cannon and demi-cannon were employed for battering, but that field-pieces or

* By Major-General Cator, C.B., Director-General of Artillery.

drakes were for sudden service, as in the day of battle. The former were mounted on block-waggons, or upon their own carriages, and required fifteen couple of lusty horses, besides the '*thiller horse*,' every two horses drawing 600 or 650 lb.: a demi-cannon required eleven horses, and the smaller drakes a number according to their weight. The rebouching of guns was first practised at that period.

The first improvement towards the present nature of ordnance took place in the middle of the 17th century; and in the reign of James II., A.D. 1686, it is recorded that orders were given to equip fourteen 3-pounders to act with several regiments of infantry encamped in Hyde Park, and two guns were attached to each battalion.

In the records alluded to is a Return of British Ordnance, dated 1669, when *cast-iron ordnance* appear to have been in use. The following Table is copied from the record:

GUNS.				MORTARS.	
Brass.		Iron.		Brass.	Iron.
Cannon of 8 in. calibre		Cannon of	7 in. calibre.	18½ in. calibre.	12½ in. calibre.
,, 7 ,,		Demi-cannon		13¼ ,,	4⅜ ,,
,, 29-pr.		Cannon	29-pr.	9 ,,	4¼ ,,
,, 12 ,,		,,	12 ,,	8¼ ,,	
,, 8 ,,		,,	8 ,,	6 ,,	
,, 6 ,,		,,	6 ,,	4½ ,,	
,, 3 ,,		,,	3 ,,	4¼ ,,	

It may be inferred from the perusal of the 'Marlborough Dispatches,' edited by General Sir George Murray, that guns were not at that period attached to battalions. At the battle of Blenheim, it is stated, that when the Duke found that he could make no impression on the enemy, he directed Colonel Blood, of the British Artillery, to take a battery across the river over which a bridge had been formed; and this artillery manœuvre contributed materially to the success of the day.

It is stated likewise, in one of the Duke of Marlborough's dispatches, dated 26th September, 1704,—"On Wednesday there arrived before Landau twenty 24-pounders, twelve 12-pounders, eleven mortars, two howitzers, and one hundred hand-mortars; and we hope in a few days to have another battery of twenty-eight 24-pounders;" and at one time he says, "we shall require 10,000 horses."

The inferior quality of the gunpowder, the charges being ⅔ths of the weight of the shot, (one-third being the present maximum charge used), must have produced the necessity for such a large supply of ordnance in the field and at sieges.

About 1736, General Armstrong, then Surveyor-General of the Ordnance, took great pains to improve the construction of British ordnance; and, profiting by his experience under the Duke of Marlborough, established certain rules for the dimensions of iron and brass guns, based upon some experiments made under his direction. These rules were as follows: For iron guns, supposing the calibre to be divided into 14 equal parts, he decided that the thickness of the metal at the vent should be 16 parts.

The thickness at the first reinforce	14·5	parts.
,, second ,, ...	13·5	,,
,, end of the second reinforce . .	12·5	,,
,, beginning of the chase . . .	11·5	,,
,, end of the muzzle	8	,,

The diameter of the vent, ¼th part of an inch.

The diameters of brass guns were regulated by dividing the calibre into 16 equal parts, when the thickness of the metal at the breach was to be 16 parts.

At the end of the first reinforce	14·5 ,,
At the beginning of the second	13·5 ,,
At the end ,,	12·5 ,,
At the beginning of the chace	11·5 ,,
At the end ,, ,, exclusive of mouldings	8 ,,
Diameter of vent, $\frac{1}{5}$th of an inch.	

The length of the guns, according to General Armstrong's construction was, for

BRASS.	Ft.	In.	IRON.	Ft.	In.
32-pr.	10	0	32-pr.	9	5
24 ,,	9	5	24 ,,	9	0
18 ,,	9	0	18 ,,	9	0
12 ,,	9	0	12 ,,	8	0
6 ,,	8	0	9 ,,	7	0
3 ,,	7	0	6 ,,	6	6
1½ ,,	6	0	3 ,,	4	6

fired with a charge of two-thirds of the weight of the shot; shewing that the manufacture of the gunpowder had not at that time improved. It is assumed that the brass ordnance were for the field, and the iron were employed in the armament of forts and ships of war.

Brigades of artillery were organised, of 12-pounders and light 6-pounders, to accompany the Duke of Cumberland in his campaign in the North of England, in 1747. This must have been the first attempt at light artillery, with certain facilities of movement without embarrassing that of the infantry.

At the battle of Minden, 1759, where the British artillery particularly distinguished itself, there were five brigades employed, composed of medium 12-pounders, light 6-pounders, and howitzers; and at the siege of Belleisle, in 1761, there were employed six 12-prs., twenty 24-prs., ten 32-prs., and several heavy mortars and 8-inch howitzers.

In 1764, when the Marquis of Granby was Master-General of the Ordnance, the following weight and dimensions were established for British ordnance:

BRASS GUNS.		Length. Ft.	In.	Weight. Cwt.	Qrs.	Calibre of Gun. Inches.	Calibre of Shot. Inches.
Heavy	42-pr.	9	6	61	0	7·3	6·68
	24 ,,	9	0	52	0	5·83	5·54
	12 ,,	9	0	29	0	4·63	4·48
	9 ,,	9	0	26	0	4·21	4·0
	6 ,,	8	0	19	0	3·66	3·40
Medium	24 ,,	8	0	42	0	5·83	5·54
	12 ,,	6	6	21	0	4·63	4·48
	4 ,,	5	0	10	0	3·66	3·40
Light	24 ,,	6	6	16	0	5·83	5·54
	12 ,,	5	0	8	3	4·63	4·43
	6 ,,	4	6	4	3	3·66	3·40
	3 ,,	3	6	2	2	2·91	2·77

IRON GUNS.		Length. Ft. In.	Weight. Cwt. Qrs.	Calibre of Gun. Inches.	Calibre of Shot. Inches.
Heavy	42-pr.	9 6	65 0	7·3	6·68
	32 ,,	9 6	55 0	6.42	6·10
	24 ,,	9 6	49 0	5·83	5·54
Light	24 ,,	9 6	47 0	5.83	5·54
	18 ,,	9 0	40 0	5·29	5·03
Heavy	12 ,,	9 0	32 0	4·63	4·40
Medium	12 ,,	8 6	31 0	4·63	4·40
Light	12 ,,	7 6	29 0	4·63	4·40
	9 ,,	9 0	29 0	4·21	4·0
	9 ,,	8 0	27 0	4·21	4·0
	9 ,,	8 0	26 0	4·21	4·0
	6 ,,	9 0	24 0	3·66	3·48
	6 ,,	8 6	23 0	3·66	3·48
	6 ,,	8 0	22 0	3·66	3·48
	4 ,,	6 0	12 0		
	4 ,,	5 6	11 0		
	3 ,,	4 6	7 0		

BRASS HOWITZERS.	Length. Ft. In.	Weight. Cwt. lbs.	Calibre. Inches.	Diameter of Shell Inches.	Charge. lbs. oz.
8-inch.	3 1	4 0	8	7·75	3 8
5·8 ,,	2 2	4 0	5·62	5·50	1 0
4·5 ,,	1 10	2 10	4.52	4·40	8

BRASS MORTARS.	Length. Ft. In.	Weight. Cwt. Qrs.	Calibre. Inches.	Diameter of Shell. Inches.	Charge. lbs. oz.
For Sea Service.	5 3	82 0	13	12·75	30 0
	4 9	53 0	10	9·75	12 8
For Land Service	3 8	25 0	13	12·75	10 0
	2 9	11 0	10	9·75	3 12
Royal	1 4	1 0	5·62	5·50	9
Coehorn	1 1½	0 3	4·52	4·40	5

The dimensions of British guns, mortars, and howitzers were not altered again until the beginning of the present century, when *heavy brass ordnance* ceased to be cast, and the weight and dimensions, as shewn in the article 'Artillery,' were adopted. It would appear that until the close of the American War, our armies were encumbered with heavy artillery, the weight of guns and carriages being out of all proportion to the means of moving them with facility.

The next change, as involving an alteration in the armament of ships, was the introduction of the carronade, about the end of the 18th century. This enabled small vessels, and the upper decks of larger ones, to carry a piece of ordnance of large calibre, viz. 18-pr., 24-pr., and 32-pr. carronades, previous to which the vessels were armed with heavy 9 and 12-pr. iron guns.

At the commencement of the French Revolutionary War, the organisation of the British artillery for the field was very imperfect; but it is a question whether, in the exercise of great guns and the nature of our heavy ordnance, much improvement has taken place, as may be proved by adverting to the siege of Gibraltar.

This fortress was attacked in October, 1779, and sustained a combined siege and blockade for four years; the besiegers commencing with 35 pieces of ordnance, which

increased to 400 of the heaviest calibre ; the final attack being a combined operation of sea and land batteries, which terminated in the destruction of the former with red-hot shot, and in raising the siege. This was probably the first successful attempt in the use of hot shot against shipping.

In the early campaigns of the war with France, in 1795, 98, and 99, in Flanders and Holland, light brass ordnance only were used, when two field-pieces were attached to each battalion of infantry, who assisted in the working of the guns : the horses procured in the country, were in single harness, and driven by waggoners in smock-frocks.

In the expedition to Egypt, in 1800, a little advance was made in the equipment of the Foot Artillery. In that campaign, after the battle of Alexandria, till which period the field-pieces were drawn by seamen from the fleet, and the army had proceeded to Cairo, a sort of Horse Artillery was formed from the companies of Foot Artillery, under Captain Alexander Macdonald, and organised as follows :

Each piece of light artillery had attached to it 1 non-commissioned officer, 7 gunners, 3 drivers, and 10 horses, distributed thus :

1st,	pair of leaders,	with 1 driver.
2nd,	,,	,, 2 extra artillerymen, mounted.
3rd,	,,	,, 1 driver and 1 artilleryman.
4th,	,,	,, 2 artillerymen mounted.
5th,	wheel horses,	,, 1 driver and 1 artilleryman.
		2 artillerymen on the limber.

In coming into action, the artillerymen dismounted from the limber and horses, whilst the drivers took the limber to the rear : 60 rounds were carried upon the limber, and the spare ammunition was conveyed by camels. A heavy brigade of 12-pounders, drawn by bullocks, was formed under the late Major-General Adye.

The organisation of the Horse Artillery took place in 1793, and the formation of this important arm necessarily led to the improvement of the foot brigades, as they were termed, until the close of the war. The first attempts at moving field artillery with more than ordinary celerity were made under the direction of Colonel Griffith Williams, Commandant at Woolwich, in 1788-9, by means of what were termed curricle guns, when the Duke of Richmond was Master-General, this Officer having had great experience in the campaigns in Germany and America. (*Vide* MS. folio in the Royal Artillery Library at Woolwich).

The first foreign service in which the British Horse Artillery was employed was that at Buenos Ayres, in South America, in 1807. This Service particularly distinguished itself in the campaigns in Portugal, Spain, and France, from 1809 to 1815.

Some discussion has arisen upon the comparative merits of Horse and Foot Artillery. Where celerity* is required, as with Cavalry and Light Infantry, the Horse Artillery is essential to a due performance of the duties, but is not necessary for the whole service, as the expense and inconvenience of the number of horses required must

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* Captain (now Colonel) Eardly Wilmot, of the Royal Artillery, gave the following evidence before the Select Committee of the House of Commons, in 1849, on the Ordnance Expenditure:

"I would mention an anecdote which was told me yesterday ; it was in a letter written by an Officer commanding a troop of horse artillery in the late campaign in India. The writer states that he was commanding a troop of horse artillery with nine-pounders ; that he was sent in pursuit with General Gilbert's force : they began at a gallop, came down to a canter, a trot, and at last came to a walk; the horse artillery armed with six-pounders galloped by them, and only pulled up when the cavalry pulled up, and was with them at the very end of the pursuit."

be considered. Quick movements, in either advance or retreat, can only be carried on by mounted horsemen, as foot-soldiers could not run far and up hill, and be then found equal to work their guns, as was experienced at the battle of Alma. (See '*Equipment of Artillery*,' Tables I., II., and III., of this work.)

The improvement in what may be deemed the efficiency of the foot batteries commenced after the Peace of Amiens, in 1801, when the corps of artillery drivers were properly organised, with the introduction of cars for the ammunition, and the gunners were carried on them: hence the batteries were called "car brigades:" these were replaced by the ammunition waggons, as at present used, (see Plates XXVII. and XXVIII., article '*Carriage*,') and the batteries formed of 5 light guns and 1 howitzer.

In the early campaigns of the Peninsula, at the battle of Vimiera the batteries were composed principally of 3-prs. and $4\frac{2}{5}$ howitzers; but as the officers and men of the Royal Artillery became more experienced in the field, the batteries were composed of 6-pr. guns with the light 24-pr. howitzers, and the 9-pr. gun associated with the heavy 24-pr. howitzer; but these howitzers have been changed for Miller's brass gun howitzers, the 24-pr. of 12 cwt. being attached to the 9-pr. guns, and the 12-pr. of $6\frac{1}{2}$ cwt. attached to 6-pr. guns. The 9-pr. guns were employed to cope with the French 8-pr. guns.

It is not, however, the perfection of the equipment alone that is necessary, it is practical knowledge in presence of an enemy, in countries in which it is difficult to move, and where forage is scarce and good stabling very rare, that makes artillerymen competent to bring their guns into action fresh, and perfect in all their attributes. Hence it was that the French, after fifteen years' experience in Germany and Italy, were always able to bring into action, in the Peninsular campaigns, with far inferior equipment and horses, a greater number of guns with heavier metal. In fact, at the early period of the Revolutionary War, the French separated the movements of artillery from infantry, although attached to them, learnt the art of acting independently, and of bringing their guns to bear upon important and vulnerable points. (See the Memoirs of the French General of Artillery, Baron Senarmont, who was killed at the siege of Cadiz, 1810).

The equipment of field artillery, although decided by a Committee of Officers in 1819, based upon the experience of the previous campaigns, is yet a subject of discussion; and it has been thought, that if the 24-pr. howitzer could be reduced in weight, and the light 6-pr. gun increased to 150 times the weight of the shot, or 8 cwt., these pieces might be adapted to Horse Artillery. It has also been conceived that 32-pr. howitzers should be associated with the 9-pr. guns for Foot Artillery, to cope with the French howitzers of 16 centimètres which accompany their 8-pr. brass guns. It appears that three of the troops of Horse Artillery were equipped in the campaign of 1813 with long 6-pr. guns and heavy $5\frac{1}{2}$ howitzers, when no difficulties occurred.

Heavy Ordnance, for Land Service, of iron, now exclusively employed in the attack of places and in the armament of forts and fortresses and for coast defences, are constructed upon nearly the same principle as regulated by General Armstrong and Desaguliers, and proposed in the experiments of Mr. Robins, which did good service at the sieges of Havannah, Belleisle, and Gibraltar, and at the Peninsular sieges when brought into use.

Sea Service Ordnance, also of iron, for the armament of ships of war, since the adoption of the heavier metal (à la Paixhan's), for shells and hollow shot, have received a new application, the 32-pr. gun being the smallest calibre in use of different weights, so as to suit the lower, middle, and upper decks of vessels: these are associated with

the 8-inch and 10-inch iron shell guns, in the proportion of one-tenth for sailing vessels, and about one-half for steam-vessels.

To save expense, and appropriate many short heavy iron guns cast for sea service, several 18-prs. and 24-prs. have had their bores increased to carry a 32-pr. shot, and serve, as before explained, for the upper decks of ships of war. (See Artillery Tables, A. and B., and Appendix I. to this article.)

This new armament has nearly doubled the force of our Navy since the Peace, as the following Table, taken from the Report of the Committee of the House of Commons on the Ordnance Department in the Session of 1849, will explain.

COMPARATIVE BROADSIDE WEIGHT OF SHOT.

In the year 1806.			In the year 1849.		
Number of Guns.	The 'Britannia,' of 102 Guns.	Weight of Shot.	Number of Guns.	The 'Caledonia,' of 120 Guns.	Weight of Shot.
		lbs.			lbs.
28	32-pounder guns .	896	12	8-inch guns . .	816
28	24 ,, ,, .	672	94	32-pr. ,, . . .	3008
36	12 ,, ,, .	432	14	32-pr. carronades .	448
10	32-pr. carronades .	320			
	Total weight of shot . . .	2320		Total weight of shot . . .	4272
	Broadside weight of shot in 1806	1160		Broadside weight of shot in 1849	2136

The problem as to the effect of the fire from this heavy armament, in future Naval engagements, has to be solved, and without the aid of steam will probably produce a series of tactical operations of an undecided nature. Against land batteries, the relative strength will remain the same when the heavy guns are used for the defence of coasts and harbours.

It has been suggested, in order to secure a consistency in the demands of heavy ordnance for the Land Service, for coasts, harbours, and sea faces of fortresses, that they might be classified so as to establish some uniformity for the Artillery Service in the following manner :

Class A. To embrace the armament of batteries for open shores and isolated spots, where ships of war could not approach within 1200 yards.

Class B. The armament of works for the protection of roadsteads and anchorages within 3000 yards.

Class C. The armament of works for the defence of harbours and mouths of navigable rivers.

Class A.

would provide for coast defences on open shores and isolated spots, which usually consist of small batteries, open or enclosed in the rear, protected by a tower or block-house or defensive barrack, to serve as a keep, or by a tower capable of mounting one, two, or three heavy guns. The ordnance most suitable for these positions might be the 32-pr. of 56 cwt. and 8-inch gun ; the keep to have one howitzer, corresponding

with the calibre of the guns in the battery, and the whole to be supplied with so much ammunition per piece, according to circumstances.

Class B. and C.

For the armament of works for the protection of anchorage, and those for the defence of harbours and the mouths of rivers, the most suitable are the 68-pr. and 10 inch guns; the number corresponding with the importance of the site. Two or more heavy mortars, if there is anchorage within 3000 yards, should likewise be mounted; the allowance of ammunition being 100 rounds per piece of ordnance.

There can be no doubt of the superior efficiency of the 68-pr. and 10 inch guns, but it may be desirable to have a small proportion of lighter metal, as the 32-pr. and the 8 inch gun of 65 and even 50 cwt.; as quickness of fire may sometimes be of great importance. The quantity of ammunition must be in proportion to the locality of the battery, and its distance from the supply.

CONCLUSION.

The object of this paper is to record the first attempts in the art of gunnery and the progressive advance and improvements in the construction of British ordnance, framed from MSS. in the Library of the Royal Artillery, from the works of various authors upon the subject, from information derived from Officers who served in the campaigns previous to the Peace of 1815, and from some experience in the field.

Although the equipment of artillery, at this time, appears to have reached a very high standard, yet it would be great presumption to say that it can go no further. "Quarter-Master Wm. Tate, of the 8th Battalion, stated, that in 1798 he was on a detachment drilled at Woolwich. It was called experimental drill; and when reviewed by the Commandant, with 3 horses to each gun in length, and driven by contract drivers, clothed in short white frocks with blue cuffs and collars, and a waggon-whip over the shoulder, Captain Spearman, then Garrison Adjutant, observed to General Lloyd, that it was impossible the movements could be quicker performed, to which the Commandant assented!"

APPENDIX.*

List of Guns supposed to have been in use in the year 1682, as found in a Ledger at present in the Tower.

Cannon of 8 inches, 11½ and 10½ feet in length.
Cannon of 7 inches, 12, 11, 10½, 10, 9½, 9, 8½, do.
Demi-Cannon, 32-pr., 13, 12½, 12, 11½, 11, 10½, 10, 9½, 9, 8½, 8 do.
,, 24-pr., 14, 13, 12, 11, 10, 9, 8½, 8, 7½, 7 do.
Culverin, 18-pr., 12, 11½, 11, 10½, 10, 9½, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4 feet in length.
,, 12-pr., 11, 10½, 10, 9½, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4 do.
Demi-Culverin, or 9-pr., 12, 11½, 11, 10½, 10, 9½, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4 do.
,, 8-pr., 10, 9½, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4 do.
,, 6-pr., 10½, 10, 9½, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4, 2⅝ do.

* By the late Major-General Dundas, C.B., R.A., Inspector of Artillery.

Jaker, 4½-pr., 10½, 10, 9½, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4, 3½, 3 do.
Minion, 4-pr., 10, 9½, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4, 3 do.
,, 3-pr., 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4, 3½, 3, 2⅝, 2½, 2 do.
Falcon, 9, 8½, 8, 7½, 7, 6½, 6, 5½, 5, 4½, 4, 3½, 3, 2½, 2, 1⅜ do.
Falconet, 7½, 7, 6½, 6, 5½, 5, 4½, 4, 3½, 3, 2⅝, 2½, 2 do.
Rabbonet, 3½, 3, 2½, 2 do.

Gun of 1⅝-inch bore, 3½ feet in length.	Port-piece of 10 inches in diameter.
Do. 1½ ,, 5 do.	Pieces with several bores.
Do. 1¼ ,, 5, 3, 2½ do.	Bases.
Do. 1⅛ ,, 4, 2⅝, 2 do.	Chambers.
Do. 1 ,, 4, 3, 2¼, 2 do.	Sling-pieces.
Piece with 7 bores.	Murderers.

An account or list of Brass Field Ordnance used in the British Service, either made new or received at the Royal Brass Foundry at Woolwich, in the year 1717, and the three or four subsequent years, to be re-cast: but by a Ledger of Ordnance Stores bearing date in the year 1682, which was saved when the Ordnance Records kept in the Tower were consumed by the fire that destroyed the Small-Gun Armoury, it appears that previous to that year the same pieces had been in use.

24-pr.,	10½	feet long,	52	cwt.	
Do.	9½	,,	50	,,	
Do.	9	,,	48	,,	
18-pr.,	10½	,,	45	,,	
Do.	9	,,	43	,,	
12-pr.,	9½	,,	30	,,	
Do.	8½	,,	26	,,	
Do.	7½	,,	23	,,	
9-pr.,	6	,,	13½	,,	
Do.	6	,,	11¼	,,	
Do.	5½	,,	9 to 8½	do.	
8-pr.,	9	,,	15	,,	
Do.	8	,,	17	,,	
6-pr.,	9	,,	13	,,	
Do.	7½	,,	12¼	,,	
Do.	7	,,	14	,,	
Do.	6½	,,	9⅛	,,	
Do.	5½	,,	6	,,	

5¼-pr.,	7	feet long,	10	cwt.	
4-pr.,	7½	,,	15¼	,,	
Do.	6	,,	4¼	,,	
Do.	4½	,,	4	,,	
3-pr.,	7	,,	10	,,	
Do.	4½	,,	5	,,	
Do.	3½	,,	4	,,	
Do.	3	,,	3	,,	
Falcons,	2¼-pr.,	6 feet long,	6 to 7	cwt.	
Do.	2¼	,,	3	,,	2 cwt.
Falconettes,	1½	,,	6	,,	9 ,,
Pattereros,	1	,,	4	,,	2 ,,
Rabbonets	½	,,	5½	,,	2 ,,
Mortars,	13-inch.				
Do.	10	,,			
Do.	8	,,			
Royal-Coehorns,	5½	,,			
Coehorns,	4⅖	,,			

About the middle of the last century, the number of different natures and descriptions of Brass Field Ordnance had been very considerably reduced: many of those before enumerated had been re-cast between the years 1740 and 1750, in which latter year the guns intended for the Land and Field Service were as follows:

24-pr.,	8	feet long,	41	cwt.	
Do.	5½	,,	16	,,	
12-pr.,	6½	,,	21	,,	
Do.	5	,,	9	,,	
6-pr.,	8	,,	19½	,,	
Do.	5	,,	10½	,,	

	Do.	5	,,	9	,,
Battalion	Do.	4½	,,	5½ to 6	
Guns,	3-pr.,	7	,,	11½	,,
	Do.	3½	,,	2½	,,
Ammuzette,	1-pr.,	6 feet long,	2½	cwt.	
Mortars,	13-inch.				

Mortars,	10-inch.		Howitzers,	10 ,,	27 cwt.
	8 ,,			8 ,,	14 ,,
	$5\frac{1}{2}$,,			$5\frac{1}{2}$,,	$4\frac{3}{4}$,,
	$4\frac{2}{5}$,,			$4\frac{2}{5}$,,	$2\frac{1}{2}$,,

After the year 1790, the guns for Field Service were—

	12-pr.,	$6\frac{1}{3}$ feet,	21 cwt.	Mortars,	13-inch.	
	Do.	$6\frac{1}{2}$,,	18 ,,		10 ,,	$12\frac{3}{4}$ cwt.
	Do.	5 ,,	12 ,,		8 ,,	$6\frac{1}{2}$,,
	9-pr.,	6 ,,	$13\frac{1}{2}$,,		$5\frac{1}{4}$,,	$1\frac{1}{4}$,,
	6-pr.,	7 ,,	12 ,,		$4\frac{2}{5}$,,	$\frac{3}{4}$,,
	Do.	5 ,,	6 ,,	Howitzers,	10 ,,	27 ,,
Battalion Guns,	Do.	$4\frac{1}{2}$,,	6 ,,		8 ,,	14 ,,
(discontinued	3-pr.,	6 ,,	6 ,,		$5\frac{1}{2}$,,	heavy, 10 ,,
about 1802,)	Do.	4 ,,	3 ,,			light, $4\frac{3}{4}$,,
	Do.	3 ,,	$2\frac{1}{4}$,,		$4\frac{2}{5}$,,	$2\frac{1}{2}$,,
Ammuzette,	1-pr.,	5 ,,	$2\frac{1}{2}$,,			

For Ordnance at present in the Service, see Vol. I. Article, Artillery-Tables, A. B. C.

There are also the Lancaster, 8-inch Gun (95 cwt.), with oval bore carrying a shell of 86 lbs. weight, and the Armstrong rifled breech-loading guns of various calibres just introduced.

ORDNANCE, CONSTRUCTION OF.

PART I.—THE CASTING OF BRASS ORDNANCE IN THE ROYAL GUN FACTORIES.*

The system generally pursued for many years, in the manufacture of Brass Ordnance, has undergone, in the establishment of the Royal Gun Factories, considerable alteration within the last three years, whereby a large saving of time and expense has been effected. That part of the manufacture which is connected with the "foundry," is now done in one sixth of the time, and at little more than a fourth of the cost originally expended on it.

The principal changes consist in the substitution of cast-iron models, for those made of loam, &c., one of the latter being required for each gun (or howitzer) cast; also, in the introduction of the mould boxes, which admit of the mould being made by the simple process of ramming the required mixture of loam and sand, in the place of the tedious and comparatively intricate process that prevailed for so many years. †

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* By Captain Haultain, R.A.

† The following description of this process was given by the late Major-General Dundas, in the former edition of this work:

"A model of the gun, somewhat enlarged in its several parts, is formed upon a wooden conical mandrel wrapped round with straw plait, over which is applied a mixture of sand and horse-dung, with water to bring it to a proper consistence; and when it is complete with its trunnions (and dolphins, if wanted), and brought to a smooth surface, and covered over with some material in a liquid state, to prevent adhesion in the after process, it is ready to give the impress to the mould which is formed upon it with well-worked moist loam, mixed with cow-hair, applied in concentric and successive layers, and into which the long fibres of hemp are carefully worked, each layer being, to a certain extent, dried over a charcoal fire made within the moulding-frame upon which the

The system now followed (1859), was introduced by the superintendent, Colonel Eardley-Wilmot, R.A. in 1856, and is as follows :—

Model.

The model is made of cast-iron, well polished, and is somewhat larger than the required size of the gun (or howitzer). From the second reinforce to the muzzle it is cylindrical.

The model is in two parts, representing the gun (or howitzer) as divided by a vertical plane passing through its axis, the trunnions being horizontal.

The section of the model thus formed, is accurately cut out of a smooth cast-iron plate, which forms the top of a box of that metal, called the "moulding frame." There is consequently a "frame" for each half-model, within which the latter is so secured, as to admit of its being raised and lowered from the exterior.

The model of the dead-head, also made of cast-iron, is separated from that of the gun (or howitzer), and is entire in one piece. It is slightly conical, for convenience in withdrawing it from the mould.

Mould Boxes.

They are made of cast-iron, perforated all over to admit of the escape of gas when the metal is run into the mould.

The box which is to contain the mould of a gun (or howitzer) is divided into two parts, to correspond with the two halves of the model. It is so constructed, that when placed over the model, portions of the upper side can be removed, to allow of the ramming of the sand, and when the mould is complete, these are replaced and secured by means of pins and cotters. The mould box for the dead-head, is made in two parts, which are however secured together before it is used for receiving the mould.

The Mould.

The mould is made of a mixture of an open sand and light loam, one part of the former to two of the latter. These are thoroughly mixed together by putting them into a mill for about five minutes. The mill consists of a circular trough, on which two iron rollers revolve ; a twisting motion also being given to them by attaching them to a short axle or spindle. After having been milled, the mixture is passed through a sieve of four meshes to the inch, when it is ready for ramming.

A small quantity of cow-hair is sometimes mixed with that portion of the sand and loam, which is rammed about the breach of the model, in order to strengthen that part of the mould on which the molten metal first falls.

Moulding.

The half-model of the gun (or howitzer) is raised so as to fit tightly into the shape cut out to receive it, in the top of the "moulding frame."

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mandrel is placed; and this is continued until there is a sufficient body and resisting power in the mould, upon which strips of hoop-iron are longitudinally laid, and all then carefully bound round with hoops, under which, in consequence of the contraction of the mould in drying, wedges of wood are driven, to keep all tight and secure; it is finally covered over with the same kind of loam mixed with water, and then carefully dried on the frame previous to the removal from within of the riable material which has formed the model; and this is done by a moderate blow or two being given on the smaller end of the mandrel: the mould is then slowly but perfectly dried before it is placed in the casting-pit.

"The mould of the cascable of the gun, and that of the dead-head, are prepared separately, and that of the latter is now joined to the top of the mould."

The model is thoroughly cleaned with oil, after which brick dust is sprinkled over it, in order to prevent the mould from adhering to it. The mould box is now placed over the model, and secured in its proper position, to the top of the moulding frame, by means of pins and cotters. The top plates of the box having been removed, the ramming of the mould is proceeded with. The rammers are headed with tin or gun metal in order not to injure the model. When the space between the model and the box has been completely filled with the rammed sand, the upper surface is squared off, and the top plates of the box replaced and secured. Sand is pressed into all the ventilating holes, through which the mould is perforated with an iron pricker, to within $\frac{3}{4}$ of an inch of the inner surface.

Mould for Dead-Head.

The model of the dead-head is placed on its largest end over a shoulder, raised on an iron plate prepared to receive it. The upper end of the model is closed with a circular plate of iron, having a hole in its centre. Through this hole is passed an iron rod, the lower end of which is screwed into the plate on which the model rests, pressing the upper end, formed into a loop down upon the top of the model, which is thus secured in an upright position.

The mould box is now lowered over the model, and made to fit over a shoulder raised on the same iron plate to which the model is secured. It is now ready for ramming the mould.

When the moulds are completed, they are washed with tan-ash and pipe-clay, mixed in water:—

8 lbs. tan-ash,
$\frac{1}{2}$ lb. pipe-clay,
2 gallons of water.

This prevents the mould from adhering to the metal.

In order thoroughly to dry and heat the moulds, they are baked in an oven for about fourteen hours, previous to which, however, the two half-moulding boxes are secured together.

When required, the moulds are removed from the oven, the dead-head box secured to that containing the gun (or howitzer) mould, and over the junction of the two boxes is plastered some worked loam, to prevent the metal finding its way through it. The whole is then lowered into a pit in front of the furnace, and is ready to receive the molten metal.

The Furnace.

The furnaces at present employed are reverberatory—they are capable of holding metal for casting one, two, or more guns according to their nature, and according to the requirements of the service. By this means, the process of casting is continued without intermission throughout the year; the men are kept constantly occupied, and at the same time, the means are at hand to supply any demand that may be made upon the establishment.

The Metal.

The metal is an alloy of copper and tin,—ninety-one parts of the former to nine of the latter. It is essential that both should be of the purest character.

Fuel.

The metal is melted with coal, in the place of oak-billets which were formerly employed for that purpose. Chemical analyses have, on several occasions, been

made, the result of which proved that the metal did not in any way suffer from the supposed impurities of the fuel. The furnace is charged both with coal and metal before being lighted. About a quarter of an hour before the metal is run from the furnace, it is at short intervals polled, that is, stirred together by means of hop-poles; and also during the whole time of its running from the furnace, the air being carefully excluded.

Under the tap-hole, so as to receive the metal, is placed an iron trough, the sides and bottom of which are coated with loam, and well dried. It extends from the furnace to the top of the mould. That end of it which is over the mould, terminates in a cylindrical pipe about eighteen inches long, which leads into the mould, and is also coated with loam. The hole in the bottom of the trough leading into this pipe, is stopped with a clay plug attached to a rod held by a man placed for the purpose. When a sufficient quantity of metal has been run into the trough, making it about six inches deep, the plug is lifted a short distance only at first, so that the metal should not fall in too great a volume upon the bottom of the mould. It is then entirely removed, and the metal allowed to run freely into the mould till it is filled, when charcoal is thrown on the top of it.

The cast remains in the pit for about 2½ hours, after which it may be taken out at convenience, the moulding box remaining on about eighteen hours longer. When the latter has been removed, and the gun (or howitzer) cleaned from the mould, it is taken to the factory, where it undergoes the following operations:—

Removing dead-head.
Centering.
Turning exterior.
Boring.
Turning trunnions.
Planing between trunnion.
Bouching or venting.
Finishing vent field and trunnion shoulders.
Engraving, &c.

All these operations are not, however, completed until the gun (or howitzer) has been proved. Only so much of them is done, as will fit it for the various proofs to which it is subjected, before being received into the service. This arrangement is adopted, in order to prevent time and labour being expended on a cast, that may prove to have some flaw or unsoundness in the bore.

PART II.—THE MOULDING AND CASTING OF IRON ORDNANCE IN THE ROYAL GUN FACTORIES.*

Previous to the year 1858 Great Britain was entirely indebted to the private founder, for her supply of Iron Ordnance.

The supply was regulated as an ordinary commercial transaction, the articles supplied having to pass certain examinations and proofs conducted under the superintendence of an officer of Artillery appointed by the Government for that purpose.

The article in question is, however, of that special nature, that something like a monopoly has always existed in regard to it.

The natural consequences of this system have been that the Government of the

* By Captain Haultain, R.A.

country has had no standard by which to regulate either the quality or price of this most important branch of war material.

Economy is evidently the medium through which the question has been looked at, and in consideration of which, a system so disadvantageous has been allowed to continue.

But the few months' experience gained by the Government establishment, working under every disadvantage, has put it beyond a doubt, that the country need not be dependent upon private founders, even on the ground of economy, for its supply of Iron Ordnance of any description.

This is, however, a question where liberality, wisely and systematically regulated, can alone constitute true economy, and that system is the most economical, which will best promote the knowledge and improvement of Artillery—one essential element of a nation's power by land and sea.

The interests of the country demand that the material best suited to the purposes of Artillery, should be known and alone employed.

Our method of proof determines nothing, as regards the endurance of Ordnance, and is a proof in name only, the existence of which is a matter of astonishment to every one sufficiently informed to understand the question.

The information required in this matter, can only be obtained by careful and extensive experiments, involving considerable expense; whereas our system of supply has been a mere commercial speculation, necessarily involving profit as the chief ingredient in the transaction. Even if the large profit secured by the founder, enabled him to carry out experiments to a certain extent, he alone obtained the information and experience, which it is his interest also to retain, thus leaving the country in the position of contributing to the support of an establishment, over which it has no control, and from the benefit of which it is in a great measure excluded.

This has also resulted in cutting off all the means, by which Artillery Officers might have become practically acquainted with a subject that so nearly concerns them.

Whatever may hereafter be adopted in regard to the material or construction of our Ordnance, there appear to exist strong reasons why the Government should have an establishment under its own control, in which to carry out the manufacture, thereby gaining all the information and experience on the subject, which it ought to be possessed of.

It can scarcely be argued that any advantages pertain to a country, from its Government being kept in entire ignorance of a subject, on which the safety of that country so materially depends.

Whatever means are taken to secure it, it is very important that the country should have in its employ, and under the control of its Government, men possessed of all the necessary experience and information, whose interests would in no manner or measure clash with the interests of the country.

The value of such men would especially be felt, when the casting resources of the country, as in the last war, should be called upon, to meet any sudden emergency. Private founders would have the assistance of men, whose experience would qualify them to superintend the manufacture of such special war material, and the country would have some guarantee that the supply was fit for its intended purposes.

In every point of view, the old system operated to the disadvantage of the country, and it is mainly due to the urgent representations of Colonel Eardley-Wilmot, R.A., that this system has at last been broken through.

The present Iron Gun Factory commenced its operations in March 1858. These have necessarily been very much of an experimental character.

The following is a description of the mode of manufacture at present carried on in that establishment.

Ingredients of Moulds.

The gun mould is made of a clayey sand, abundant in the neighbourhood of Woolwich; the proportion of clay being small.

The property of the sand is to make a porous mould, not contracting with heat, and retaining its form with great firmness, when assisted with a small proportion of clay. Too much of the latter would cause the mould to contract when heated.

A small quantity of coke and coal dust is mixed with the sand. The dust formed of one of coal to two of coke, is added to the sand in the proportion of one to eight. It tends to bind the mould, but at the same time adds porosity to it. It should be pure, not containing more than one per cent. of sulphur, as the formation of sulphuret of iron, when the molten metal is run into the mould, would act as a cement, tending to make the mould adhere to the cast, and causing much additional labour in removing it, before the gun can be turned.

Milling.

The sand and dust are well mixed together in a mill. The mill consists of a circular iron trough, on the bottom plate of which two iron rollers revolve, a twisting motion being given to them by attaching them to a short spindle or axle.

After having been milled, the mixture is passed through sieves of four meshes to the inch, when it is fit for ramming, and is used for every part of the gun mould, except the cascable. That part which receives the latter is strengthened by having cow-hair mixed with it, in order to enable it the better to resist the first fall of the molten metal.

The sand and hair are milled together, the rollers employed having projections or teeth on each side, in order to mix them more thoroughly.

This mixture is baked quite dry and afterwards ground, when equal quantities of it and the sand, with the proper proportion of coke and coal dust, are milled together, and passed through sieves as before.

Model.

The model of the gun and dead-head is made of cast-iron, the projecting parts, such as the base ring and the swell of the muzzle, being made one-eighth of an inch larger in diameter than the required gun.

From the second reinforce to the muzzle the model is cylindrical, or rather so far conical, as the diameter of the first reinforce exceeds that of the swell of the muzzle.

The model is divided into parts for the convenience of moulding. In long guns the following divisions are made :—

1st. The cascable.
2nd. From the neck of the cascable to the rear of the base ring.
3rd. From the rear of the base ring to the rear of the first reinforce ring.
4th. From the rear of the first reinforce ring to the centre of the trunnions.
5th. From the centre of the trunnions to the middle of the chase.
6th. From the middle of the chase to the swell of the muzzle.
7th. From the swell of the muzzle to the middle of the dead-head.
8th. The remainder of the dead-head.

All the parts of the model are cast separately, and have, with the exception of the cascable, an inner flange at each end, by means of which the parts are screwed together, and the whole model accurately turned to the required dimensions.

When required for forming the mould, each part is attached, by means of the inner

flange, to a cast-iron circular plate on which, concentric with the model, is a raised shoulder, for the mould box to fit round, and thus to give the required thickness of sand to the mould when rammed.

Mould Box.

The mould box is also made of cast-iron, being divided into parts to correspond to the divisions of the model. With the exception of those for the cascable and breech, which are each in one piece, all the boxes are formed of two longitudinal halves, with exterior flanges perforated for bolts.

The two halves are secured together when required to receive the mould, and loosened when the mould is to be removed from the cast.

The boxes are also cast with external flanges round the upper and lower rims, which are perforated with holes for pins and cutters, by which the various boxes containing the mould are fastened together, when lowered into the pit to receive the molten metal.

In order that the boxes may fit each other accurately when put together, there is a raised shoulder on every alternate flange, with a corresponding depression in the others. All these are finished off in a lathe, to secure the greatest exactness.

The trunnions are cast separately and in halves, and are screwed on to their respective parts of the model.

Moulding.

The breech model is secured to the plate, the largest diameter downwards. The mould box is placed over it, and the mould rammed.

The cascable is then fastened to the breech by means of an iron pin, passing through the former and screwing into the latter.

The cascable mould box is placed over the model and the mould rammed. A circular cast-iron plate is then fastened over the upper surface, on which the whole mould box rests in the casting pit.

Part 4 (from the first reinforce ring to the centre of the trunnions), is secured to the plate with its trunnion end downwards. After the mould is removed, the model is unscrewed from its trunnions and withdrawn, the mould being afterwards raised. In all the other parts the larger diameter of the model is downwards, and the mould when rammed can therefore be drawn over it.

Iron rods with the head somewhat enlarged, are employed in ramming the different parts of the mould, which when finished are washed with a blacking made of coke dust and clay water. They are then baked in ovens for about 36 hours, and not withdrawn until required for use, as it is important to have them perfectly free from moisture.

Furnace.

The furnaces employed are reverberatory. Their dimensions are as follows.

DIMENSIONS OF FURNACE.

Exterior.

Length	23 ft. 3½ in.
Width	6 ,, 7 ,,
Chimney	6 ,, 4 ,,

Interior.

Length	14 ft.
Width	5 ft. 3 in.

Depth	At well	3 ft.
	At throat	1 ,, 1 in.
Width at throat		3 ,,
Chimney		2½ feet square.
Height of Chimney		57 ,,

Experience is the best test of the right proportions to be given to any furnace.

It is not desirable to have one part of the metal melted any length of time before another, and therefore the general melting capabilities of the furnace and fuel, must determine the quantity of metal beyond which a furnace should not be charged.

The larger furnaces of the Establishment could contain twelve tons, but they are never charged with more than half that quantity. If the gun to be cast requires more than six tons two furnaces are employed. The fires are lighted and the furnaces heated, before the latter receive the charge of metal.

Casting Pit.

Owing to the low position of the foundry, in order to keep them free from water, it was found necessary to line the casting pits with boiler plates rivetted together. There is now no difficulty with them.

There are ten pits, one to each furnace. They are each twenty feet long by eight feet wide. Half the number are twenty feet, and the other half fifteen feet in depth.

Two guns are cast in each pit, but were it necessary, the pits could hold double that number.

The moulds rest on a cast-iron plate which is supported on two brick walls, raised the required height, on the bottom of the pit, which is thus in a great measure protected from injury.

Fuel.

It is commercially known as the best, Yorkshire converting coal. A sample of every cargo is analysed, and that which is small or that which contains more than one per cent. of sulphur is rejected. The coal used should be capable of producing great heat, under the ordinary circumstances of an air furnace.

Iron.

As has already been stated, one of the chief objects of the establishment of the Iron Gun Factory, was to ascertain the variety of the metal and the treatment of it best fitted for the manufacture of Ordnance.

Experiment alone could determine it. The object has been kept constantly in view, forming however but a small part of the work required of the establishment.

So many shades of difference exist in the iron products of this country, that a very extensive series of experiments is necessary to arrive at a satisfactory conclusion in regard to their merits, either when used separately or when mixed in different proportions with each other.

The question is, moreover, of such wide extent, that it would be premature to draw any conclusion at the present time, but thus much seems probable, that with due care on the part of the manufacturer of the Pig Iron, with a view to this special purpose, there may be obtained in this country metal of such a quality as will leave little to be desired, ever remembering that the great desideratum is purity.

It may very properly be mentioned here, the valuable services rendered to this, and to every other Government manufactory, by the department under the able superintendence of F. A. Abel, Esq., Chemist to the War Department.

There is little doubt but that the analyses to which the material supplied to the departments is subjected, and on the result of which in a great measure depends its reception or rejection, will tend to raise the quality of such articles generally.

Running the Metal.

The metal does not run immediately from the tap-hole to the mould, but is received into a reservoir, capable of containing the quantity required for the gun.

The reservoir is a four-sided wrought-iron box with its interior coated with loam, which is dried before use. Wrought-iron gutters also lined with loam, conduct the molten metal from the tap-hole to the reservoir, and from the latter to the mould. An opening in the side of the reservoir nearest the mould, is covered with an iron door coated with loam.

When the required quantity of metal has run into the reservoir, this door is lifted, when the metal flows into the gutter, by which it is conducted into the mould.

The gutter terminates in an iron loam coated pipe, about 3½ inches in diameter, which passes about eighteen inches down the centre of the mould.

Its object is to give a perpendicular direction to the flowing metal, which is thus prevented from striking against the sides of the mould in its descent.

Trunnion Plates.

To prevent the impurities floating on the top of the metal, from entering the trunnion holes of the mould, they are covered by wrought-iron plates. These plates are attached to long iron rods, the tops of which project about eighteen inches above the mould.

Two men attend to these rods, holding them firmly in their proper position until the metal has risen above the plates, when they are withdrawn.

Removing Cast from the Pit.

The larger guns are allowed to remain from four to five days before they are removed from the pit.

The parts of the mould box above the trunnions, are drawn up before the cast is raised. In order to do this the pins and cotters securing them together are removed, and the longitudinal fastenings loosened. The whole is then raised and the remainder of the mould also removed.

Boring Mill.

When the cast has been cleared from the mould it is taken to that part of the establishment, called the Boring Mill, where it undergoes many other operations. (*Vide* Table.)

With every gun, there are also cast from the same metal and at the same time, two bars and a ring. The former 20 inches long by 2 inches square, the latter of the same diameter as the testing ring of the gun.

The testing ring is that part of the dead-head immediately beyond the muzzle which is left on, as by it the fore part of the gun is suspended whilst undergoing some of the operations enumerated.

The above specimens of the iron of which each gun is made, are subjected to mechanical tests, the description of which, as well as of the several examinations and proofs a gun undergoes before being received into the Service, more properly comes under the head of "Proof of Iron Ordnance."

Operations, in their order, performed in the manufacture of Iron Guns. The number of the various machines in the establishment. The average time for each operation, with a 68-Pounder Gun of 95 cwt.

	Operations.	No. of the Machines in the Establishment.	Time for each operation for a 68-pr. gun 95 cwt. in hours.	Remarks.
1	Cutting off dead-head . .	2	3	
2	Centreing	2	5	
3	Turning exterior. . . .	6	20	
4	Planing between trunnions.	1	5	
5	Turning trunnions . . .	3	12	
6	Turning shoulder of do. .	1	3	
7	Roughing		22	Each Boring Machine may be used for either of the three boring operations.
8	Scopping } Boring . . .	20	10	
9	Finishing		5	
10	Cutting off testing ring .	By centreing machine	3	
11	Turning cascable . . .		4	
12	Finishing about the trunnions, ventfield and loop, also fixing the block in rear of the cascable .	By hand	30	
13	Drilling hole for breech pin	By venting machine	1½	
14	Venting	2	2½	

DESCRIPTION OF THE MACHINERY, ETC. USED IN THE MANUFACTURE OF BRASS CANNON AT THE ROYAL ARSENAL, WOOLWICH.*

In no department of practical science has there been a more rapid advancement during the past fifty years than in the construction of tools and machinery for cutting wood and metals. While many causes have operated in producing this result, there is one agency, which from its apparent simplicity we are apt to overlook, but which has been the chief instrument in accomplishing so remarkable an improvement, namely, the introduction of the sliding rest principle, by means of which the cutting tool is held in an iron hand, and is unerringly constrained to move in a definite line towards the production of the required form without being dependent so far as form is concerned, upon the attendant. Before the invention of this admirable contrivance, every separate operation in producing any piece of work required in the construction of machinery had to be performed by manual dexterity. In the process of turni a circular piece of metal, the cutting instrument was held and guided by the muscular strength and skill of the human hand, which was ever liable to err; and, in the pro-

* By John Anderson, Esq., Inspector of Machinery, Royal Arsenal.

duction of other forms such as flat or irregular surfaces, the tedious operation of the chisel and file had to be resorted to, the work thus performed being consequently not only imperfect but necessarily most expensive.

By the varied application of the sliding-rest and other modifications of the principle of production by copying,—in contradistinction to that of obtaining the form by the skill of workmen,—an extraordinary development has been given to almost every branch of the metal and wood manufactures, both in our own and every other progressing country; and, by keeping steadily in view that the object of such machinery is to have within the apparatus the mathematical forms which are required in the articles to be produced, the apparent complicacy will vanish and render the mechanism employed to make such apparatus available—easily understood.

By this combination of guiding the cutting tool in preconstructed lines, instead of having it held and determined by the skill and physical power of the workman, together with the introduction of the self-acting or automaton principle whereby not only the form but the movement and the rate of cutting are contained in the machine, the operation, so far as the workman is concerned,—with the exception of sharpening and fixing the cutting tool,—may be considered as entirely mental. It is interesting to observe in passing, that the great and distinguishing peculiarity of the turning lathe, even in its most primitive form of construction, such as in the old Gun-boring mills of a hundred years ago, and that from which its success was wholly derivable, was the mathematical circularity obtainable by causing it to turn upon a central axis, an invention probably coeval with the use of a pair of compasses for describing circles, and which, in all likelihood, had suggested the idea of the lathe principle. By causing a gun or other article to turn upon a centre-point, and holding the cutting-tool steadily, either by the hand, or still better by fixing it in some rough and ready vice, as was the custom in the olden time, a perfect circle at the muzzle would be secured, which circle, when made to revolve in a bearing, had its accuracy transferred to the opening of the bore for the introduction of the boring bit, the construction of which was again adapted for still farther transferring the truth and circularity of the muzzle through the entire length of the bore.

In the construction of modern turning or boring lathes, there is not only the means of securing such circularity by convenient and handy arrangements; but, in addition, they produce as a result of the invention of the machine for planing flat surfaces, extreme accuracy in the parallelism of the lines of the several parts. This arrangement, together with the slide-rest, or copying, and the self-acting principles, enables the workmen to produce the smallest and the most ponderous piece of mechanism with equal facility, and with a mathematical precision which is difficult to be appreciated by those who are not practically conversant with the subject. And not only is it in turning and boring the lathe that the advantages of the slide-rest, copying and self-acting principles are made available, but also in all the other kinds of machines that are employed in cutting metal into other forms beside the circular; and in no application have the advantages of these principles been more usefully developed than in the variously constructed machines for planing either flat, horizontal, vertical, angular, concave, convex, or irregular surfaces. In all these are the straight or other mathematical lines to be copied from the apparatus and transferred to the work under operation, as also some mechanical arrangement for overcoming the resistances of the metal to be cut, for giving the movement to the several parts of the mechanism, and for actuating the self-acting portion of the apparatus. By means of these planing machines we are enabled to produce any description of surface with a facility and accuracy, which, before its introduction, were never dreamt of: and without it, there are many parts of the machinery about to be described that could not have been

executed except at an inordinate expense, which would have practically precluded the adoption of such refinement, however desirable.

The machinery and tools now employed in the manufacture of cannon in the Royal Arsenal, have been all constructed within the last twenty years.

Previous to the year 1765, the bronze cannon made at Woolwich were bored in a vertical position muzzle downwards, the gun was cast upon a loam cone a little smaller than the required bore, the gun was then suspended between vertical guide poles and made to rest upon the cutting instrument employed in smoothing out the interior; by means of levers, the boring bar was turned round by several men walking in a circle upon the floor, the gun meanwhile was allowed to descend gradually upon the boring bit until the bore was completed.

It would be difficult if not impossible to produce a perfectly true and straight bore with the tools and means then employed, but it is questionable if while adopting the more convenient and economical arrangement of horizontal boring, there has been an improvement in the obtainment of concentricity, or in the mode of getting rid of the chips from the boring-bit; and notwithstanding the fact that our more recent constructions designed and recommended by the writer are on the horizontal arrangement, still he would here record his opinion that if again called upon to design a boring-mill, from observations and the experience of the last twelvemonths, he would re-consider the question very carefully before recommending that the horizontal method of boring should be adopted.

About the year 1765 an entire new plant of boring machinery came from the Hague, for at that time the Dutch were the great engineers of the world, and it is curious to find that the masters and leading workmen of the Gun Foundry were either from Holland or Germany up to a recent period: it was only in 1803 that the first Englishman was intrusted with the management of a boring-mill, and the last of the race of foreign mechanics left about 1818. These foreign workmen appear to have been far in advance of our men, both in regard to refinement in their ideas and in workmanship, they had veritable slide rests for certain processes in mortar-boring and turning, which although rude as compared with the more modern applications of the principle, still had the germ, and these no doubt had been seen by that great man, the late Henry Maudslay, who is generally considered the inventor of the sliding-rest. He served his apprenticeship in the Royal Arsenal and doubtless must have been familiar with those wonderful tools of the Dutchmen; still it is by no means certain, for it is amusing to find how exceedingly tenacious they were of all their secrets, and to notice the careful manner in which every boring bit and tool was covered up whenever a stranger was seen to pass towards the door of the mill, which for greater security in this respect was always kept barred and bolted. At that time each boring lathe was placed in a separate mill or building, and to each of them was attached a four-horse mill, the motive power being blind or otherwise defective horses belonging to the Royal Artillery. Upon the end of the shaft which brought the motive power from the horse-mill there was a square box or chuck, and into this box or chuck there was inserted a square lump which was cast upon the extremity of the breech of the gun behind the cascable.

The muzzle of the gun ran or revolved in a circular collar plate, which was kept firmly in its place by means of strong iron bolts connected to a foundation of iron-work and heavy masonry, unmistakeably indicating the sound ideas of the engineer by whom the plant of machinery was originally designed.

In the process of boring, the bit was forced into the gun by means of an endless screw with rack and pinion, which was gradually and carefully turned by a man or a boy, while the laborious operation of turning the outsides of guns was effected

entirely by hand tools. When the guns were thus bored and turned they were removed to another building to be vented and turned at the trunnions. Here it was placed on blocks of wood while the several holes were drilled, which was performed by two men with a crank brace drill, the pressure being communicated from heavy weights placed above.

The copper vent was drilled in a small lathe, the motion being given by two men turning a fly-wheel, while the drill was held in the hand of a third workman. In the same lathe the vent was turned and the screw formed upon it, both operations being performed by hand. When the copper vent was screwed into the gun, the projecting part inside the bore was cut or wrenched off by means of a half round bit moved by hand. The gun was then taken to another building to have the trunnions turned, here it was placed on blocks of wood with the trunnions in a vertical position, one of the trunnions was then divided off by gauges and a pair of compasses, about a quarter of an inch of the extremity was cut to the proper diameter by the chisel and the position of the trunnion determined thereby. Upon the part thus finished there was placed a circular box or socket having a cutting tool fixed upon its under side, while at the upper side there was attached a vertical spindle which received pressure from weights placed upon the top. Long levers were then attached to this apparatus and several men kept walking round in a circle until this part of the trunnion was completed, the extreme end was finished by the chisel and file; the other trunnion was then turned uppermost and the same operations repeated upon it, after which the gun was placed on a carriage and taken to another building to be finished off by hand in the parts not yet completed, and also to be engraved.

Such was the rude, tedious, and imperfect system in 1842, when the necessity of a change became apparent to the then Inspector of Artillery, the late Major-General Dundas, R.A., C.B., who, perceiving the backward condition of the several manufacturing departments, entered with zeal upon a course of improvement—all the more honourable in that he was the first to encounter the then almost insurmountable obstacle of obtaining money; for in those days of strict economy, it was no easy task to effect even the smallest improvement: but by his untiring perseverance, very great improvements were effected, and his example having been followed up by his successors (more especially the present talented superintendant), the manufacture of cannon has been entirely remodelled and extended. The writer of this paper has been the mechanical engineer engaged in carrying out most of the several changes.

There being two distinct manufactories of cannon in the Royal Arsenal, one for brass and another for iron ordnance, we shall first describe the machinery of the former, it being the oldest and first established.

Brass guns are usually cast solid, in a vertical position, with the breech downwards. Upon the muzzle or upper end of the casting, the mould is prolonged for three or four feet for the purpose of increasing the density in the lower part of the mould by means of the fluid pressure arising from the superincumbent metal contained in this prolongation, it also allows the sullage or scoria to rise towards the surface and out of the metal composing the gun proper, and it affords a reservoir of liquid metal to allow for the shrinkage that takes place in the lower part of the mass or casting. This elongation upon the upper end of the gun is technically called the dead-head.

The process of gun-casting (as now practised in the Royal Brass Foundry), will be found treated of at length in its own place, but it may be here remarked in passing, that the proper material for the moulds of brass guns is not yet very satisfactorily determined; and there is considerable difference both in opinion and practice with regard to its nature and conditions. It is generally considered that that is the most

perfect, which may be found to possess the several qualities of indestructibility, and the not containing of any organic or other substance which may evolve gas. For the last two hundred years, English, German, and Dutch founders have employed a mixture of silica and alumina in such proportions as would render the silicious portion plastic and adhesive. In the neighbourhood of Woolwich, a fine natural loam is found almost ready to the founder's hands, but in general, the founder has to carefully select his clay and his sand, and then to mix them in proportions suitable for the intended purpose.

A perfectly pure silicious mould, if by any possibility it could be secured, would doubtless afford a high result in every respect, but from its want of adhesion when in the condition of pure sand it is unfitted for this purpose both in holding together as a mould, and in bearing the flow of the liquid metal. The iron greensand founder is enabled to use a mixture not far removed from this ideal, namely, 96 of silica, 3 of alumina, with probably 1 of organic impurities. But such a mixture is deficient in stiffness for brass gun casting, more clay is required, even if used as sand, and considerably more so if it is to be the mixture called loam. It might be presumed that sand moulds would be superior to those made of loam, but here other causes interfere that tend greatly to affect their conditions as moulds for casting in. When loam in the plastic state is employed, it is or ought to be not only baked but made red hot, in order to evolve the gases near the surface, which is brought into contact with the liquid metal, which gases the impurities or other substances mixed with the loam may contain; by so doing a moderately good mould is secured so far as freedom from gas holes in the casting may be concerned: but another objection presents itself in such a mould, namely, its great porosity, arising from the process which allows the metal to penetrate and combine with the inner crust of the structure. Until lately such a substance and mode of procedure was carried on in the arsenal, and nearly perfect castings were uniformly produced thereby, but the plan was open to the said objection, and the percentage of loss of metal was greater than when a closer mould made of purer material can be ventured on.

The material now employed in the Royal Brass Foundry consists of a mixture of clean sand and loam, forming a sand containing about 90 per cent of silica, about 8 of alumina, and probably 2 per cent of impurities mostly organic. The first ingredient is the only essential one, any other non-gaseous but adhesive substance would serve for the second, and the sand would be all the better if it could be obtained without any of the third. This sand when rammed hard into the form of a mould and well baked previous to its reception of the metal, is found to answer moderately well, but it is always exposed to the risk of impure substances capable of germinating gas when in contact with the high temperature of the liquid metal, and their force is apt to create air-holes both in the casting and near to the exterior surface of the gun or other article, unless it is sufficiently tenacious to sustain the burning process.

These considerations have directed the attention of brass-founders in various parts of the world, after other substances that possess the required conditions of a mould, without the disadvantages attending the use of sand or loam. One of the best of these materials, namely, pounded fine brick, has been extensively used by the inventor of the soft metal for bearings, Mr. Babbit, who has been a very successful caster of brass ordnance; he carefully selected the old fire-bricks that had stood the brunt of a furnace without changing colour; these were ground in a mill to a fine powder, and then rammed into a mould in the same manner as sand, this mould was afterwards put into a kiln and thoroughly dried. The surface of the mould was then washed over with a coating of a liquid made by grinding a portion of the same fire-brick with a little water until it became like cream.

The mould is again placed in the kiln, made red-hot until the surface is vitrified, then prepared for the liquid metal; by this means an indestructible, non-gaseous and impenetrable mould is secured.

Another material which has been adopted by Mr. Ames, of Chicopu, is found to answer the purpose equally well; it consists of the substance termed kaolin, used for making china ware; this is carefully selected, then ground fine to a powder, and rendered adhesive by a small quantity of pure pipe-clay water, and then used in the same manner as the fire-brick mould. Both the fire-brick and the kaolin, from their purity, afford a better material for this purpose than either loam or sand, unless they could be obtained perfectly pure and entirely free from any vegetable or mineral substances capable of generating gas.

A considerable effort was made a few years since to exhaust the air and other gases from the interior of the mould previous to and during the reception of the liquid metal; but the advantages were not found to warrant the trouble and expense involved in carrying out the process.

To render the description of the machinery more distinct, it is expedient to take a gun as it comes from the foundry, and refer, in passing, to the fifteen distinct processes to which it is subjected during the manufacture.

The first operation in the gun manufacture is to cut off the dead head; this is performed in a turning lathe of the ordinary construction, but having some additional apparatus which was designed by the writer in 1848, adapting that machine to this especial purpose. By means of a crane the rough gun is placed within the lathe, having the cascable inserted into a holder or chuck upon the end of the running and driving spindle, (fig. 1., Plate I.) while the other end is supported by allowing the muzzle to rest in a bearing of peculiar construction, with the dead head projecting over. (Fig. 2.) This apparatus for holding the muzzle of the gun, will be understood by reference to that figure. A represents a section of the cannon, lying in an adjustable bearing formed like the letter V; it is made of the V form in order to adapt it to different diameters, which it does by means of the vertical adjustment; a hinged bar, B, is laid over the top of the gun to prevent it from rising upwards when a thick shaving is being sliced off by the parting-tool. As the rough gun is irregular in form, this bar is kept down by a helical spring, the elasticity of which adapts itself to those irregularities.

The cutting or parting-tool, C, is held in a sliding-rest, which is not shewn, by means of which it is moved in a horizontal line towards the centre of the mass of metal, or until the dead head drops off; to prevent this falling mass from damaging the lathe a log of wood is laid across the bed, upon which it falls; this operation requires from twenty to thirty minutes.

There are three chief points requiring to be observed in adjusting the apparatus to perform this operation: first, to place the gun in a level position, or at least parallel with the lines of the lathe bed; second, that the cutting-instrument, which consists of a thin bar of steel, may have sufficient clearance to avoid unnecessary friction, that is to say, that the cutting edge make an incision sufficiently broad to admit the tool without touching the metal of the gun; and thirdly, that the cutting edge of the instrument is set to cut in a line about the fiftieth of an inch under the centre; if this line is above the centre it is constantly liable to catch hard into the metal, and get broken, or if it is much under the centre the point is apt to break off, from the direction in which the strain of cutting comes against it.

The second operation of manufacture is to find the centre of the mass of metal, and then to drill a conical hole at both ends of the gun; these two holes constitute what are termed the centres or axes upon which the gun turns during the future processes of manufacture.

The principle upon which this operation of finding the centre of a mass is dependent, consists in having certain points on which to rest the gun, these points being so constructed as to be equally distant at all times from a fixed centre, and by arranging the drills that make the conical holes to be always in the line of the fixed centre referred to. The machine which is employed for this operation was designed by the writer in 1843. It was the first machine used for this purpose, and is defective in some respects; since that time several others have been constructed, both for our own and other countries; one of the best and most recent will be found referred to under the head of Iron Ordnance.

Fig. 3 is a plan of the centering machine. A is a cast-iron bed resting upon three legs or standards B. The upper edges of the bed are constructed in the form of $\wedge$ (or angular) and flat surfaces, all correctly planed and forming true and parallel supporting surfaces for the several parts of the machine to rest and slide upon.

C C are two frames or saddles resting upon the lathe bed and fastened to it when adjusted for particular guns by means of bolts (*h*). Each of these frames is provided with three slides, two horizontal, and one vertical, and all have a simultaneous motion by turning the handle wheel (*i*); by turning in one direction all proceed towards the centre of the machine; by turning the other way, the three slides proceed at an equal rate from the centre, and the points or extremities of each of the three slides are equally distant from the centre in every position.

Fig. 4 is an elevation of this saddle frame; it contains, first, the two horizontal slides (*k*), and second, a vertical slide (*q*). The two former are actuated by screws formed on the spindle (*l*). The one screw however being cut to the right hand and the other to the left hand, they necessarily move in opposite directions to or from the centre. The vertical slide is actuated by a similar screw, receiving its motion from the horizontal screw spindle by means of a pair of bevel wheels, both wheels having an equal number of teeth; it therefore follows that by turning the handle the three slides move to or from the centre simultaneously; and consequently, if the extremities of the slides are in the construction of the machine made equidistant from this centre, it is evident that any round mass laid upon the vertical and then raised upwards until the horizontal slides grip, the gun will be brought thereby into a centrical position.

E E fig. 3, are two hand-drilling machines placed upon the bed, having the axis of the drilling spindles made to coincide with the axis or centre line of the centering slides. Motion is given to the drilling spindle by means of the fly wheel and handle F, the smaller hand wheel (*v*) is for feeding the drill forward as it gradually cuts its way inwards.

Fig. 5 is a section of this part of the machine: a screw is cut in the boss of the wheel (*v*), into which is fitted a corresponding screw that slips loose upon the spindle; along the outside of this screw a groove is cut, into which is inserted a key that is fast in the cylinder (*u*): this key is to prevent the screw from turning while the wheel (*v*) is turned. The back part of the spindle is smaller than the drilling end, which gives a shoulder to the screw to press upon, while a pin through the spindle at the other end of the screw serves to bring it back again. A key let into the end of the spindle slides in a groove in the boss of the fly-wheel, and thereby receives its motion.

To centre a gun with this machine, it is only necessary to place it between the slides (*k*), and turn the handles (*i*) until the horizontal slides grip the gun, which brings the centre of the mass exactly opposite the centre of the drill.

The drilling heads are now brought forward, the fastening bolts are tightened, the workman with his right hand turns the fly-wheel (F), and with his other hand gently

moves the hand-wheel (*v*) which feeds the cut. The whole operation, including the putting the gun into the machine and taking it out again, may be accomplished in less than a quarter of an hour.

The third operation is to put the gun into an ordinary turning lathe, but made expressly for this purpose, in order to have certain parts of the exterior surface turned; this is done partly to reduce the amount of turning required during the fourth operation, and to have certain rings formed for assisting the determination of the position of the various parts, this having to be regulated by the actual condition of the mass as a casting, for it will sometimes happen that a defect may exist at some part which may, by some alteration of the centres, allow that defect to be cut entirely away without injuring the gun in any respect, whereas if the workman was at once to determine these points by the position of the centres in the casting, it would frequently be otherwise. In this operation the centres made in the centering machine are made available for the gun to revolve upon as an axis, and by forming the lines referred to, the position of the base ring, the vent field, and the trunnions, and roughing down certain parts of the outer surface towards the formation of the muzzle, altogether requiring about ten hours, the gun is then ready for the fourth operation. In this operation the gun is subjected to the twofold process of being roughly bored out within one-eighth of an inch of the finished dimensions; and also in having the turning of the exterior still farther advanced, but not yet completed.

Plate II. contains a plan of one of the lathes employed in these operations of boring and turning. It was designed by Mr. D. Napier, of London, and afterwards altered in the driving arrangements by the writer. The same machine is also employed in the operations five and eleven. A, is a strong and massive bed of cast-iron, resting on the floor of the building; the bed is cast in two pieces, and firmly joined in the middle. The top surfaces of the bed form a $\wedge$ and flat, and are accurately planed; so that the different parts of the machine which rest upon the bed have the same relative position to one another in any situation, and without any adjustment. B is the spindle or mandril of the lathe; it runs in gun-metal bearings or pillow blocks of beautiful construction. The principal bearing (*a*) rests on C, an elegant yet substantial pedestal of the same metal; D is the turning saddle, on which is placed the turning slide-rest (E); F is the collar-frame, in which runs the muzzle of the gun. G is the boring apparatus which rests upon, and is bolted to a strong bed of cast-iron Q, which again rests upon and is bolted to the lathe bed. The boring bar that carries the boring bit on its extremity slides upon the boring bench G.

The boring bed is strongly built of mahogany, and firmly bound with iron bolts and plates. The parts where the bar slides, the ends under the advancing screws, and those places where there are fastenings, are strongly faced with gun-metal. The object of having the bed of wood is to avoid tremor. The boring bar (R) is the instrument on which the bit for boring is fastened. In forcing the bit into the gun, there is a great tendency to twist the bit and bar round with it: to prevent this, there are three strong cross-heads (S), with a boss at each end, and a large boss in the centre, for the pressing screw, on one of the end bosses; the cross-head swivels on a stud securely fastened to the bench in order to facilitate the operation of changing the boring bar. As these bars are of different sizes, and as it is necessary to have them in a certain position, with reference to the axis of the gun, in order that the cutting edge of the bit may be in right place for the best conditions of incision into the solid metal; this bench is arranged to rise and fall by means of four screws worked simultaneously by the handle T.

By reference to the description of the boring lathe employed for iron ordnance, it will be seen that the several requisite conditions are secured by entirely different

arrangements, and which in some respects are considered better, although this method is not without its peculiar advantages.

The boring bar R, receives its motion for penetration by means of the two screws U, which are worked from the wheel and pinions V. This wheel can be worked by the hand, or made self-acting by a motion from the running spindle of the lathe; but the communicating apparatus is not seen in the drawing.

The turning part of this machine is contained in the slide rest, E, which is fixed on the saddle D, but adjustable to the different angles required for guns, or may be set parallel with the axis of the lathe, and may be worked either by hand or made self-acting from the shaft (*g*).

In order to adapt the turning apparatus to different guns, the saddle D may be shifted along the lathe bed to the required position, without interfering with the self-acting motion, the shaft (*g*) being made with a continuous groove in which fits a feather or key in the pinion, which is thus adapted to slide upon and receive motion at any part.

The really important point to be understood in connection with gun boring, is the source of the truth or circularity in the bore and its perpetuation inwards, so that it may be concentric with the exterior surface of the gun. In the present case truth is derived from the turning of a ring around the muzzle of the gun during the third operation; here truth originates, and on that depends whether the gun bore is to be round or oval. As before observed, the muzzle turns on a fixed centre point, and is cut by an instrument which is stationary, so far as the axis is concerned, and therefore a true circle must be formed. But if it were arranged in such a manner that the centre and its spindle revolved with the gun, then there would be a chance of error in the spindle not being round, for whatever its shape may be, that form will be hereditary in all its future productions until rectified.

When the gun is put into the boring lathe this true muzzle-circle is made to run, during the boring process, in a bearing, which is fixed in the standard F, and a V drill is then introduced to roughly open out the commencement of the bore, but without giving truth, as ten to one it will wobble about to a small extent, although entered correctly into the centre made in the gun; truth has to be obtained elsewhere.

The muzzle ring being true, if a stationary instrument is introduced that will be so rigid as to prevent its being affected by the eccentricity made by the V drill, then the circularity of the muzzle ring will be transferred to the commencement of the bore; this is here accomplished by means of a slide rest fastened to the end of the boring bench, and in some of the lathes upon the headstock. Into this hole the boring bit is inserted, the grand function of which is to continue the truth and dimensions of the same onwards to the further extremity of the bore. The bit therefore is an instrument not only to bore but to transfer the original truth at the same time. Bits are of two classes, round and half round; in both they fit the part commenced, but the latter are chiefly used for brass guns in the Royal Arsenal, and differ only in construction from those introduced from Holland one hundred years ago. It consists of half a circle, having one of the radii as a cutting edge adapted to penetrate into the metal in front, a bearing being obtained from the finished part of the bore for the half round bit to rest upon.

It might be supposed, judging from the theoretical conditions, that accuracy would be secured by the first bit, but such is not the case, although it is frequently difficult to ascertain the cause or causes of aberration, still it is so, probably in most cases arising from inequality in the metal or air holes. This has to be rectified by a future boring on the same principle.

Dimensions depend on the bit; if the line of the cutting edge is above the half

diameter, the effect is to thrust it onwards from the centre until the cutting edge is in the line of the diameter, or if it is under the line, it will not have a proper bearing, but will chatter and produce an irregular hole. Hence the manipulation of the bit and its working involves a considerable amount of skill, which a little experience alone can give.

The breech ends of guns are supported in two different ways.

The chief condition to secure is that the axis of the gun and that of the boring bar may coincide and form a straight line; this, therefore, is aimed at, but is rarely obtained, but as the gun revolves during the process, every side alike has the same chance of getting astray, and hence it is found in practice that the bore is produced with considerable straightness, although seldom mathematically correct. If the gun was not nearly in the same line (as it always ought to be), and if at the same time the bar was perfectly rigid, a gradually widening bore would be produced, but these conditions seldom or never exist to such an extent as to produce this result. With regard to the truth of the gun's movement at the breech end, this, although also important, is not so to the same extent as at the muzzle, because the truth or roundness of the bore is transferred from the muzzle by the conditions of the boring bit. But so far as it affects the turning of the exterior service, it depends entirely upon it; hence there are two ways of supporting guns during the boring process. When the spindles of the lathe are imperfect, and with rough machinery, it is found most advantageous not to depend upon the apparatus, but to turn a true bearing at the breech end the same as at the muzzle, and to allow the gun to run in these two bearings by giving it motion from an independent spindle; with this arrangement the gun is so far right, always providing the axes of the bearings are in a line with the axis of the boring bar.

With good machinery, however, the running spindle is made in a line with the boring bar, and is also made true in itself, so that the future truth of the breech is secured once for all in the original good workmanship of the apparatus; thus obviating the daily labour of securing the same conditions for every gun. Of course as the bearings wear in both cases they will require fresh adjustment, and when the lathe spindle wears out of round it will require to be made true again, and when too bad after many years' service, it will either require to be renewed, or the bearing for the breech of the gun substituted, for which there is always due provision. In all the lathes of the Royal Arsenal, the truth of the breech is dependent on the machinery as being the most convenient for manufacture; still it is a matter of opinion as to which is positively the best arrangement.

The fifth operation is to enlarge the rough bore to within a small fraction of the finished dimensions, in order to prepare it for a proof to test its general efficiency as a casting, more especially in regard to its soundness in the interior of the mass, which is invisible to the criticism of any examination.

This operation is performed in a boring lathe similar to the former, and with a half-round boring bit constructed on the same principle; in performing this operation the bit is pushed into the gun at a greater rate per revolution than during the previous process of quarrying out from the solid metal. In the former case the rate of progress is fourteen inches per hour, this being the utmost that the cast steel of 1858 will admit of; to go faster would result in broken boring bits and greater disaster to the gun, and no matter how powerful the lathe may be made, the quality of the steel cutting edge together with that of the metal to be cut, are the points which really determine the rate of progress. In reboring, however, a greater speed can be employed in consequence of the small quantity to be removed not exciting the temperature, so that the usual speed is twenty inches per hour.

In the first operation the mere removal of solid matter was the chief object, the bit was made with a radial line in front only, and adapted to chisel out a continuous screw or spiral shaving, equal to half the diameter from the commencement to the conclusion of the bore. Owing to the disruptive action of the instrument, however, the continuity of the spiral shaving is disturbed, and the borings are obtained in the condition of chips. It being evident that a considerable amount of mechanical power is required to so pulverise the said chips, that arrangement of bit or cutter which will afford an equally good bore with the shaving in larger masses of curled brass will be an improvement; but there being so little scope in the confined space of a bore to exercise any improved modifications of arrangement, such bits are much the same as those used a hundred years ago, except so far as having the cutter in a slide to admit of fine adjustment and promoting its endurance.

In this second boring a smooth and straight bore is the object aimed at; here the bit is arranged to cut not only in front, but also to cut off a clean smooth shaving at the side; by this means great smoothness is obtained.

The sixth operation is the proof. The gun with its rugged exterior is removed to the proving ground, and if found during its first competitive examination to afford the evidence of soundness, it is returned to the boring mill with a certificate according to its general behaviour.

The seventh operation is to have the trunnions turned. The gun being now considered serviceable, this is performed with the conviction that the labour and expense will not be thrown away. Until lately this preliminary proof was not employed, and the turning of the trunnions was an earlier operation in the manufacture. Plate III. contains a plan of the trunnioning machine designed and made by Mr. Napier of London in 1842.

The gun lies horizontally, being supported on the centre at the breech and by the bore at the muzzle; the cutting instruments being at right angles in fixed headstocks with moveable spindles. A. is a strong foundation bed that binds the several parts of the machine together, the bed B is bolted to the former, and is for supporting the adjustable saddles that hold the gun, the adjustment being effected by means of the screws (*a*) by the handles (*b*). As the trunnions of most guns are under the centre, it is necessary to have a vertical adjustment, hence the holding centre and the cone for the bore are attached to vertical slides; these slides when at rest on the bottom of the part in which they slide in the saddle, have the holding centre and the centre of the cone on the same horizontal plane as the axis of the cutting spindles, but when the trunnions are under the axis of the bore, the vertical slides have to be raised accordingly, the adjustment being effected by means of the handle (*c*). By having an index on the vertical slide, the workman is enabled to set the gun in position with perfect accuracy.

The driving shaft E passes through the foundation bed and gives motion to the spur wheels, F, through the agency of two pinions not seen in the drawing.

The turning frames or headstocks H are bolted to the foundation bed and set with the spindles in a perfect line at right angles to the gun. The spindles G contain at their inner extremity the cutting chisels (*k*), while at the other side wooden rubbers (*m*) act as a stay to the cutting tool.

The spindle G receives motion from the wheel and socket, of which it forms a part, by means of a groove or keyway in the spindle, in which fits a corresponding key fastened in the socket (*h*), so that the rotation of the wheel and socket gives a motion to the spindle, while the groove in the spindle allows it to move endwise, as may be required: the motion for feeding the cut may be wrought self-acting or by hand. J is the self-acting feeding motion, shown in gear: to throw it out of gear, and work

by hand, it is only necessary to push the wheel (*o*) back to the head of the stud (*q*), and turn the handle. The manner in which the self-acting motion is produced is very ingenious. The end of the spindle (G), which is farthest from the turning-tool, is bored out hollow; into the tube there is fitted a spring, with four arms that force outwards: this spring is keyed on the end of a small steel shaft, having a small steel pinion on its other end: this pinion gears into the wheel (*o*), which, by the long pinion keyed on its boss, gives a motion to the wheel (*r*). The wheel (*r*) is keyed on the end of a screw, which is connected to the spindle (G), and so gives it the forward motion. One great advantage of having the motion through the spring is, that when the tool comes to any place on the trunnion where it cannot get forward, the spring slips in the tube, and no mischief arises.

As was observed before, to disengage the self-acting motion, it is only pushing the wheel (*o*) out of gear with the steel pinion on the end of the spring-shaft; and as the pinion on the boss of the wheel (*o*) is double the breadth of the wheel (*r*), it still remains in gear with *r*, so that the hand-wheel (*o*) retains a command over the spindle. K is a fly-wheel on the end of the driving-shaft (E), by which the workman may turn the tool round by hand, when he requires to do so. L is the strap-lever, by which the machine is thrown out or into gear: it is wrought by the handles (*n*). M are the fast and loose pulleys.

Before putting a gun into this machine, the workman divides off the distance of the centre of one of the trunnions from the base-ring, and then describes a circle. The gun is placed between the centre and cone. The gun is adjusted with a spirit-level. He knows by the drawing how much the axes of the trunnions are below the axis of the bore; so that by the handles (*c*) he raises the gun, setting it to the index as the gun requires: he then fixes a scriber where the turning tool is fastened, and by turning it round carefully by hand, he sees if the line it makes coincides with his former division; if it does not, the gun is shifted by the handles (*b*) until it is brought to its true position. The fastening bolts (*g*) are then tightened; and to prevent the gun from moving during the operation, it is wedged up underneath.

Both trunnions can be turned at the same time, the whole operation occupying from five to seven hours.

Nothing can exceed the accuracy by which guns are trunnioned with this machine. As the spindles are at right angles to a line drawn through the centre of the gun, the trunnions must be at right angles to the bore; and as the axes of the spindles are in a straight line, the axes of the trunnions must be in a straight line with one another. Its chief defect is the arrangement of having the spindles to slide in the headstocks; having them stationary like the spindle of a turning lathe, and the headstocks to move instead, would be better.

The eighth operation is to plane that part of the gun which lies between the trunnions, it being more convenient to remove the metal in this manner than by circular turning. Formerly this was done by hand with the chisel and file, afterwards it was accomplished by the slide rest turning apparatus of the boring lathe, by making the slide rest alternate rapidly while the gun was made to turn slowly; thus it will be seen that the terms planing or turning may mean the same thing.

The chief objection to the performance of this operation in the boring-lathe was, first, the having to dismantle the turning and boring part of the apparatus for the time being, and second, by having to plane with that which was only fitted for what is called turning, hence much time was wasted, not only of the workman, but of an expensive machine, and the performance of these operations occupied six hours.

In 1845 the planing-machine, Plate IV., was designed by the writer, by means of which the planing between the trunnions is performed in an hour.

The gun is on centres between two headstocks, the spindles of both being free to turn; the one headstock, A, is a fixture, the other, B, being adjustable to suit the length of different guns. The spindle in the fixed headstock is made self-acting by means of the double ratchet arrangement (*a*), invented by Mr. Clements. The slide-rest, C, which carries the cutting-instrument (*b*) is placed alongside the gun, and is adjustable not only in regard to its position on the bed to suit different lengths, but also in regard to its position with reference to parallelism. Most guns are tapered, hence this slide-rest must be fixed in the right line to produce that figure.

The alternating motion of the slide is obtained from a crank, D, placed on the top of a vertical shaft as shown, the power being derived from a pair of fast and loose pullies, E, with a bevel wheel, F, and pinion, G, between to increase the power by reducing the speed. The amount of traverse given to the slide-rest, as also the rate at which the gun turns, are both adjustable and under the control of the attendant.

To plane or turn two movements are requisite; first, the movement to cut off the metal, and second, the forward movement to overtake the whole surface; in turning the gun revolves at about twenty-five revolutions per minute, against an almost stationary instrument; if it were stationary altogether little work would be done, but it has a self-acting slow motion forward, and this combination effects the object. In planing, this combination is reversed, the instrument for cutting has the greater motion, about forty cuts per minute, while the gun has the smaller motion; it is well to see the chief points, because the mode of doing it, or the manner of constructing the machine, may be affected or varied in many ways. The great condition is to have a cutting-instrument with penetration, and the requisite amount of strength; it may then be pushed against the metal, or the metal may be pushed against the tool; in each case the effect will be alike, it is for the engineer to select the arrangement, or modification, that will be the most convenient for the intended object.

The ninth operation is to drill the gun for the reception of the copper vent, and also for the tangent scale.

Plate V. shews side and front elevations of the drilling machine designed by Mr. Napier, with a section of the spindle: the same letters in all the figures apply to the same parts.

A is a strong frame of cast iron, in one casting; it is bolted to the wall of the building by the four bolts (*a*), with wall-plates on the outside. B are the fast and loose pulleys: on the same axle is keyed the cone pulley (C). D is a corresponding cone pulley, keyed on the same axle as the wheel (*b*). The object of having the cone pulley is to obtain a variety of motion; for example, a hole of $\frac{1}{4}$-inch in diameter would be drilled with a much faster motion than a hole of 2 inches diameter. By having the cone pulleys, the workman may have the motion that best suits his work, by shifting the strap on the proper division of the pulley. S is the strap which connects the two pulleys; the wheel (*b*) gears with the wheel (*c*); the boss of *c* is fitted into a socket in the frame, and the drilling-spindle receives its motion from the wheel by a key and groove. Pressure to the drill is obtained by means of the hand-wheel E, acting upon a screw socket surrounding the spindle.

Plate VI. contains the different views of an apparatus for holding the gun, which was designed by the writer in 1844. The trunnions of the gun are laid in two supports formed like the letter V, with the breech resting on a table; both the supports and the table are adjustable in all required directions, so that the gun may be set at any angle with reference to the drill above it; at the same time, from the supporting V's being level, the trunnions are always correct, irrespective of any care on the part of the workman.

In adjusting the gun, a graduated plumb-level is applied to the muzzle, the drill-

table being raised or lowered by means of the handle (*h*), for actuating the elevating screw until the gun is at the right inclination, the other adjustments being obtained by means of the other handles shewn.

The operation of drilling holes is exactly on the same principle as that of gun-boring, only that in the one case the drill revolves, while in the other it is the metal. Drills are made in many different ways, the most common, and those used in the brass gun manufacture, being the half-round bit and the V drill, more especially the latter; but in all, the requisites are strength and penetration. The principle of the half-round bit has been referred to already, that of the V drill is a very ancient invention. A hundred years back, the drill was seldom made to revolve continuously as in modern times, but to revolve alternately backwards and forwards by means of an elastic lath, hence the origin of the term lathe, or a beam fixed in the roof of the building, and connected to the drill by means of a string wound round it; smaller drills were worked in the same manner by a bow like a fiddle stick, the string being wound around the drill and played by the workman backwards and forwards. With such a motion the cutting property of a modern drill was not attainable, but it had to be ground on both sides and edges alike in form similar to a lancet, and by the wriggling motion it scraped its way inwards.

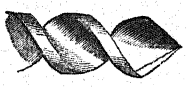
A proper V drill (fig. 1) consists of a pair of chisels formed on the end of a piece of steel, and placed at an angle of 45° to each other, and meeting at a fine point: by causing this drill to turn on its axis, each of the two chisels cut out a shaving from the solid metal. By examining the conditions of cutting, it will be seen that a V drill made only as above described is wanting in the property of penetration. In order to produce the best result, it is necessary to have the cutting edges twisted forward, thus giving it the appearance of a screw: by this means it acquires the penetrating property without being weakened, and will perform many times the amount of work without heating or breaking.

Another important point is to have the V point exactly in the axis of the drill, and the two inclined chisel edges exactly at the same angle. This may seem so obvious as to require no observation; yet it will be found that for one drill which is right in this respect, ten will be wrong.

Fig. 1.



Fig. 2.



In drilling small deep holes—such as that for the tangent scale—there is always the risk of the chips choking up the way, causing the drill to stick fast and to break. Until lately, holes of this class were cleared by taking out the drill, and using means to fish out the chips; but within the last twenty years, an important improvement has been made in twisting the body of the drill into a spiral form, thus making it the agent to worm out the chips as it revolves (fig. 2).

The only correct and expeditious mode of grinding drills is to fix them in a holder concentric with their own axis, and to cause the holder to revolve or turn in front of the grindstone: thus the two edges must be alike. Again, drills are mostly always ground away too much behind the cutting edge; this is done to give penetration, but without consideration, as it does not affect the property in question, and only gives weakness instead.

The tenth operation is to put the copper nut into the gun. The copper is cut from

the bolt into the required length, then put into a lathe, and bored out like a miniature gun, only it is bored through and through; it is next put into another lathe, and turned and screwed to the proper dimensions.

The screw is formed within the gun by means of an instrument technically termed a tap; it is a bar of steel, having the required screw, originally formed upon one end; it is then cut away in such a manner as to have only three equally distant portions of the threads to act as cutters: this, when tempered, is introduced into the hole in the gun, and when turned round, either by a lever with the hand or by the power of a machine, it gradually screws and cuts its way to the bottom.

Taps were formerly made square, thus leaving only the full threads of the screw at the four corners. A moment's reflection, after it is once pointed out, will show that such an instrument is only capable of bruising its way inwards: yet the world went on for two thousand years after the tap was invented before it was made three-sided, and at the same time hollowed out, so as to convert the three corners into cutters, by which improvement the tap is made steadier, the friction is reduced, and the teeth are made cutting instruments.

The hidden virtue that lies in the sacred number three was long unknown to the mechanical world. The name of the inventor of the three-legged stool has been lost; but the principle which he found out is only beginning to be appreciated, and is now being applied by all who are aiming at perfect conditions of surface under varying conditions of support. Mr. Whitworth, of Manchester, has done much to develope the principle, and applies it in the way indicated in all his finer instruments for measuring, surfacing, screwing, and the like.

When the screw is cut in the gun, the copper vent with its corresponding screw is inserted, and worked home by means of a lever.

The eleventh operation is to finish the bore. By the fifth process the bore was brought almost to the required dimensions. After having the various operations ranging from six to eleven performed, it is again put into the boring lathe to have the bore finished off, and to rectify the slight irruption which is necessarily made when the vent is inserted. The instrument employed is either a blunt condenser or a half-round bit. The advantage of the former is, that without cutting away any of the metal, it enlarges the bore, by thrusting it outwards by main force. This secures two advantages, and one disadvantage: it makes the gun-metal forming the lining of the bore harder and denser than its natural quality, while the more exterior metal is allowed to retain its original softness and tenacity; it also stops up any small air-hole by pushing the solid metal into it. The disadvantage arises from the great friction thereby created, thus enlarging the diameter of the mass due to the increase of temperature; hence the bore is apt to be irregular, and if care is not employed, it will sometimes endanger the gun.

The other method is that of carefully boring out the thin shaving, which makes the best finish; but the bore is softer. Both plans are frequently combined, by leaving about the 100th of an inch to be removed by the bit.

It should here be mentioned that where great accuracy and parallelism of the bore are aimed at, the difficulty of securing these conditions is frequently tedious and troublesome; and a minute acquaintance with the subject will invariably show that there is all the difference between a thing that is right and another only nearly right. In the previous borings, the bore to an ordinary examiner would pass for right, when it was, nine times out of ten, only nearly so; hence it is rare to find the finished bore correct in its parallelism the first time. The gun warms, and the bit wears: the two causes combined render the bore tapered: and it will scarcely be credited, that to arrive at absolute perfection, it is sometimes, with certain descriptions of metal,

necessary to pass down the readjusted boring bit several times. The writer has seen it done six times without being positively perfect after all. Still, with moderate metal it is frequently found sufficiently correct for all practical purposes by the first passage of the finishing bit.

The twelfth operation is to finish or chisel off all the irregular parts that have not yet been attempted by any of the previous machines. Hitherto we have been dealing with straight lines, flat surfaces, circles, cylinders, cones and portions of spheres; but there yet remains a number of intricate places, such as the roots of the trunnion shoulders where they are united to the body of the gun, the vicinity of the vent-field, the dispart and other parts which are of irregular form.

The careful student will have observed that in the production of the several regular forms alluded to, they were all more or less obtained by some modification of the principle of copying, by having the form within the apparatus, and having the line, the surface, the circle, or cone, or cylinder, secured by transfer from something or other carefully made beforehand. It is important to make a full recognition of this as a principle, because, when fully understood, it greatly tends to simplify and open up the whole question of such a manufacture.

The class of apparatus employed in the production of more irregular forms, although quite different, and to a superficial observer a distinct speciality, still it will be found only another modification of the all pervading copying principle.

The performance of these several operations may be conveniently explained under two heads.

First, where the irregular form is cut by means of a single-pointed tool, and second, where the form is obtained by means of a revolving instrument having a number of cutting points.

The peculiar figure developed by the junction of the trunnion shoulder to the body of the gun, and more especially when the trunnion is on the axis of the bore, is chiselled to the required form by means of a tool with a single point. In determining between the merits of the one class and the other, the consideration which influences the choice, is not always regulated by that which would perform the operation in the most direct manner, but partly by the financial question of economy of manufacture; the instrument with a number of cutting points technically termed circular cutters or milling tools, is of more expensive construction than the other, and although it might be inferred that with a hundred teeth, it would chisel off one hundred times the quantity before getting blunted, yet in practice it is found that the numerous chances of the cutter getting into contact with the hard exterior crust or particles of grit upon the metal, expose the instrument to the risk of losing its fine edge, hence subjecting the manufacturer to the expense of resharpening it, a process much more tedious than with the single point, which can be easily sharpened at a grindstone. On this account the single point is generally preferred whenever it can be applied.

In the employment of such a tool in the operation of cutting round the root of the trunnion, an arrangement was designed by the writer in 1850, which answers very satisfactorily. The revolving spindle which carries the single cutting tool on its extremity nearest to the gun, is made to revolve in a position with its axis in the line of and coinciding with the axis of the trunnion, but constructed in such a manner that it is free to obey any longitudinal influence while it revolves. In order, therefore, to give it a determined path to revolve in, a figure of the required irregular form is attached to the apparatus, and the spindle is compelled to trace this form or copy by means of a small roller; thus as it goes round, it at the same time moves out and in, in the mathematical figure to be developed. But something more is still required; the removal of this metal is not effected at one revolution, as such an instrument will

not cut off a shaving more than the fiftieth of an inch thick at one turn round; hence it may require a hundred or more revolutions to effect the object, while at the same time it is made to advance at this rate of the fiftieth of an inch per revolution. To accomplish these conditions, it is only necessary to have the entire apparatus which contains the spindle, as also the pattern or copy, made capable of this gradual advance, either by a self-acting arrangement or by hand.

In the machine for performing this operation to brass guns, the idea explained above was an afterthought, and forms an additional apparatus, requiring to be put on for the occasion. But in constructing a new machine for the express object of turning this part of iron guns, it has assumed a better form, which will be seen by reference to the paper on that subject.

The single instrument not being so well adapted for the irregular surfaces and corners of the dispart and vent-field, the circular, or many-pointed instrument is substituted.

In using this description of tool to perform the different operations upon a brass gun, it is necessary to have a headstock similar in construction to that which carries the running spindle of a turning lathe, but so arranged that it may be moved about up or down, forward or backward, to the right or left, and at the same time to have the motion in each position. In addition, it is also necessary to have the means of giving a slow rotation to the gun when required; with this combination, a good deal can be effected.

To take the dispart in its several positions, under the performance of the operations, may afford an illustration.

Fig. 3.

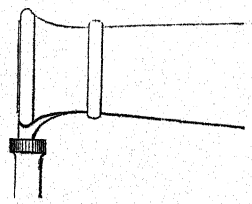


Fig. 4.

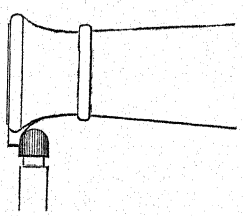


Fig. 3 shows the face of the dispart being cut to the proper length. The axis of the cutting spindle and that of the gun being on the same plane, we may suppose the cutter moving either to the right or left.

Fig. 4 shows a cutter forming the back of the dispart; here the shape is partly in the cutter, and the gun may be supposed to be moving slowly round, with the axis of both on the same plane.

Fig. 5.

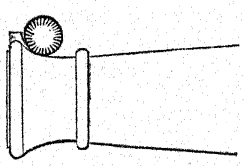
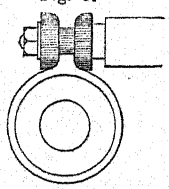


Fig. 6.



It would be effected almost equally well, as shewn in Fig. 5, by having the cutter of a diameter that would coincide with the required curve. Here the axis of the

spindle is raised above the gun, and a motion may be given to the gun, or the cutter may be moved transversely!

In the same or in a similar manner the sides of the dispart are cut, or it may be done by two cutters fixed on a spindle, as in Fig. 6, and caused to run right and left on the straight lines contained in the slides of the machine.

The parts in the vicinity of the vent-field and the tangent scale, are done in a similar manner, and need not be described. It must be confessed that none of the machines yet applied in shaping guns by means of these circular tools are perfect; they are all too rigid, and the cutter is not sufficiently free to move over a copy of the required shape. Much is left to the guidance of the attendant, who has to employ considerable skill in directing it.

To make a perfect single machine to perform so many different and distinct operations involves a greater cost of construction than the work and saving of labour would warrant, while at the same time it is not considered advisable to have special machines for each operation, as that would involve a larger expenditure on plant than the limited number of guns to be manufactured will warrant or render profitable; under the circumstances, therefore, it is a compromise, using machinery so far as it will pay, leaving the remainder to be done by hand labour.

Before leaving the subject of circular cutters, it may be mentioned that a great improvement has been made in the mode of sharpening them within the last few years. The system was first practised in America and introduced to England by the writer after a visit to the United States in 1854.

The circular cutter is made of cast-steel, and after having been turned in a lathe to the required shape the teeth are cut upon its surface by means of a machine similar in arrangement to that employed for cutting the teeth of wheels, then hardened and tempered in the usual manner. Until recently, when such tools required sharpening, they had to be softened and then cut to the fine edge necessary for work; but as all softenings and hardenings involve the heating of the steel, its quality was soon greatly injured, besides the expense of the operation. In heating a mass of steel, and then suddenly cooling it to produce hardness, there is always a considerable risk of fracture, in consequence of the exterior surface becoming cooled and contracted before the inner body of the mass, and here, contrary to the general rule, strength is an element of weakness, for the larger the mass the greater the risk.

By the new plan these risks are reduced, as one hardening process suffices for many sharpenings.

On a small lathe resembling those used by the lapidary, there is mounted on the end of the running spindle, a small circular cake of a composition of fine emery, glue, and a little shell-lac, which has been made by casting the mixture in a metal mould of the required shape. This instrument is driven at several thousand revolutions per minute.

The workman in sharpening a cutter, sits upon a stool with his arms resting upon the lathe bed in order to steady his hand, presses the teeth very delicately against the sharpener, and by moving it along the edge whets it with the utmost exactness and facility.

The form of the teeth of such cutters has occupied much attention, so as to secure the two conditions of cutting smoothly, and at the same time to be easily sharpened. The most common arrangement is to have the teeth in line with the axis, or in radial lines when they are to cut in front; but it is found that when such teeth are long, the great hold which they take of the surface is an objection, hence other modifications are frequently adopted; one of which is to cut a screw on the toothed surface of the cutter, thus leaving spaces which break the continuity of the shaving.

A good arrangement is to cut the teeth upon the skew, and when the teeth are very long, to have portions of the skew teeth in opposite directions; and in the construction of very complicated circular cutters, they are made up of a number of distinct rings, the sum of which, when strung together on the mandril, forms the complete instrument, and when requiring to be sharpened, it is reduced to rings, each unit being simple and easily manipulated on the small grinder.

The thirteenth operation is to finish and plane off the exterior surface by hand. With all our boasted fine machinery of slide rests and such like appliances, there is a point beyond which its assistance is not remunerative; so far as accuracy is concerned, it fulfils every requirement, and any addition of hand work only helps to reduce the quality; but there is a smoothness and shining surface together with greater facility in getting into all the crooks and turns obtained by the hand tool which will be difficult to arrive at by any system of mechanism. This operation is performed in a lathe, with the gun revolving a little faster than during the previous processes; the hand tool being laid on a rest and gently applied over the whole surface.

The fourteenth operation is also performed by hand; the gun is laid on a pair of tressels and, by means of the chisel and file, any remaining point not yet overtaken by the planing and shaping machines is finished off, and the gun is then entirely completed, with the exception of the engraving, which is the fifteenth and last operation; this also, at the present time, is performed by hand. It would be easy to make a simple machine to perform a considerable portion of the engraving process, leaving only the more delicate touches for the hand-tools; such machines, indeed, are already in existence, and the only hindrance to the introduction of one to this operation is the commercial consideration of economy of manufacture. It costs some thirty hours wages to engrave the gun by hand, by the machine and hand combined it will occupy about twenty, to which is to be added the interest on the first cost of the machine, together with the expense of keeping it in working order. All such machines are copiers of the required engraving, a correct transfer of which is transmitted to the article being engraved by means of a revolving tool, which chisels away the metal wherever it can reach, its guide being a tracing point pressing on and passing over the surface of the pattern.

It is natural for the engineer to desire to shew the complete control of mind over matter by the entire performance of these several processes by machinery, leaving only to the attendant to guide and direct by his governing intelligence, but after all, it is a more pleasing conclusion to find that wonderful organ, the human hand, and that still more wonderful organ, the human brain, by which the hand is directed, still maintaining their superiority.

INDIAN FOUNDRY, ETC.*

The Foundry of the Honourable East India Company for the manufacture of brass ordnance for India was originally established in Fort William, upon only a limited scale; the boring and turning of the machinery being worked by bullocks: but in 1826, Captain G. Hutchinson, of the Bengal Engineers, being appointed Superintendent and Director of the Foundry, he was permitted by the Government of India to return to England, with the view of obtaining new machinery for the establishment of the foundry upon a more enlarged and efficient footing. Accordingly, under the orders of the Honourable the Court of Directors, Captain Hutchinson submitted plans of machinery for the foundry to be worked by steam, prepared by Messrs. Hall and Sons,

* By the late Colonel Hutchinson, F.R.S., Bengal Engineers.

of Dartford, upon a much improved and self-acting principle of operation, to which Captain Hutchinson added the important improvement of effecting the accurate *turning* of the ordnance by means of the machinery, as well as the boring of the guns, by which a much greater degree of accuracy of metal is insured; also, after visiting the foundries abroad, he introduced some further improvements in the mode of turning the trunnions, and in the construction of a locomotive crane, by which a considerable expense was saved.

Previous to the removal to India of this beautiful and scientific machinery, executed with the greatest accuracy by Messrs. Hall and Sons, Captain Hutchinson had the honour of submitting plans of its principle of construction to the then Master-General of the Ordnance, Lord Beresford, who appointed a special committee of Artillery Officers to examine and report upon it. Captain Hutchinson met the committee at Messrs. Hall and Sons' Foundry at Dartford, and exhibited to them the great accuracy and celerity with which the new self-acting machinery executed the work, and especially the great importance of the arrangement by which the slide-rest (carrying the turning tool) turned with mathematical precision the outside of the gun, liable to be so inaccurately turned by hand. This principle, though differently executed, has now been introduced into the new machinery erected in the foundry at Woolwich.

Plate VII. shews the general plan of the new foundry of India, erected by Captain Hutchinson, near Calcutta, on his return with the machinery in 1829.

Plate VIII. the plan of the self-acting principle of the lathes.

Plate IX. shews an improved mode adopted in the construction of the reverberatory furnaces, by making the bottom of the furnace to ascend, instead of descending as usual from the fire-place: the flame being also thrown upon the metal more in the manner of a blow-pipe, the power of the furnace was greatly increased, half the usual time only being required to smelt the charge of the furnace.

Plate X. Plan of a large syphon, 247 feet in length, and 5 inches interior diameter, cast and fixed by Captain Hutchinson, for the supply of water from a distant tank to the well in the foundry: a small pipe being attached to the air-pump of the steam engine, and the syphon kept under water by a small pipe from the overflow cistern, it was always found to work efficiently.

Plate XI. Section of the iron trussed roof erected over the boring-hall, nearly 170 feet in length, 50 feet span, and 40 feet in height, the whole of which was put up and finished without any scaffolding from below.

Moulds.—The mode of making the ordnance moulds in India is in loam (a preparation of clay and cut rope). A model or pattern of the gun to be cast being turned in wood (due allowance being made for the shrinkage of the metal), along with the proper length of dead-head, the model is oiled over and a layer of loam spread over the upper half, about one inch thick, in which are embedded half-circular pieces of hoop-iron, placed about 4 or 5 inches apart: when dry, another layer of loam is put on with hoop-iron, embedded as before, together with longitudinal bars about $\frac{2}{1}$ ths of an inch thick and one inch wide, placed 2 or 3 inches apart, running the whole length of the mould: when dry (the iron being covered with loam), the model is turned over, and the other half finished in the same manner: when the whole is perfectly dry, the two halves are separated, and the wooden model removed. The interior of the mould is then dressed and made perfectly smooth, and the two halves being joined together, are strongly hooped with iron, and covered with another layer of loam, which completes the mould. It is then removed, when dry, to the casting-pit, and burnt red-hot, and before it is cool the metal is run into it.

The new foundry, when completed, was found capable of executing with the greatest accuracy any description of machinery required, as well as the preparation of the ordnance; and such was the efficiency of the improvements introduced, that Lieut.-Col. Hutchinson was able very greatly to reduce the cost of casting and turning the ordnance for India, whilst the important desideratum of perfect uniformity was established throughout all the Presidencies.

ORDNANCE DEPARTMENT.—This *was* a distinct branch of the War Department of the British Empire, originally instituted for the supply of all warlike stores used in the Naval and Military Services. According to Haydn's 'Dictionary of Dates,' the first Master of the Ordnance was created in Henry the Eighth's reign; and probably the Tower of London was the original dépôt of arms and military stores. Kane's 'List of Officers of the Royal Artillery' gives Robert, Earl of Essex, as the first Master-General, in 1596.

An Ordnance Department was not peculiar to this country, as the Government of the United States of America has a similar establishment, forming a part of its War Department, for the supply of military stores.

It does not appear that the Ordnance Department of this kingdom became especially military until the early part of the eighteenth century, after the organisation of the Royal Artillery in 1743, under the Duke of Montague as Master-General: previous to this, the duties were confined to the supply of cannon, ammunition, and stores to the Navy and Army.

From this time the Ordnance Department was administered by the Master-General and Board, the latter being composed of a

Lieutenant-General of the Ordnance,
Surveyor-General,
Clerk of the Ordnance,
Principal Storekeeper,
Clerk of the Deliveries, and
Treasurer;

the Lieutenant-General presiding at the Board, assisting the Master-General in his military capacity, and acting for him in his absence.

This appointment, and those of the two last officers of the Board, have been suppressed. After the peace of 1763, the Engineer Corps was formed, when the Ordnance Department became a Constructive Board, with charge of all forts and fortresses, and directed the construction of all the fortifications and military storehouses and barracks for the Ordnance Corps.

Charles, Duke of Richmond, as Master-General from 1782 till 1795, consolidated and regulated the duties of the Ordnance, and organised a Board of Officers, called Respective Officers, representing the Master-General and Board at every permanent station in the empire, to maintain the regulations of the Department, and to secure a joint responsibility in the expenditure of money and stores. This Board is composed of the

Commanding Officer of Artillery,
Commanding Engineer, and
Storekeeper.

The orders framed by that distinguished man of business are the basis for the management of the Ordnance to this day, at home and abroad.

CENTERING MACHINE.

Fig. 3.

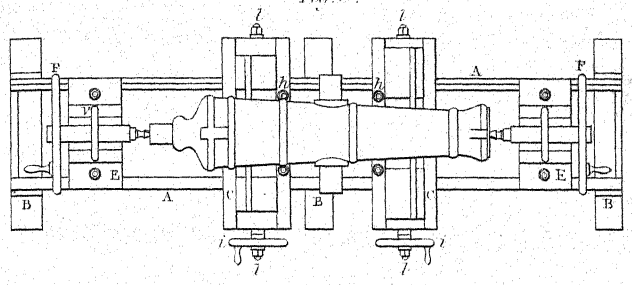


Fig. 4.

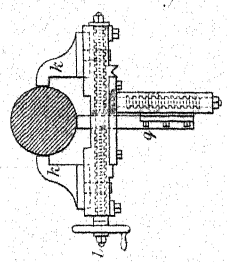


Fig. 2.

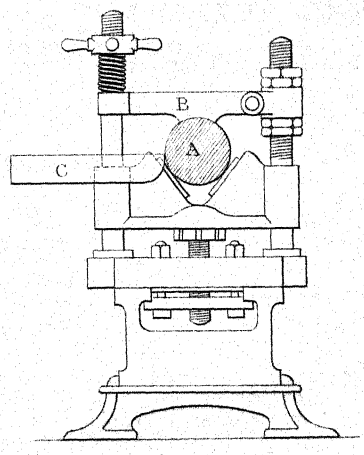


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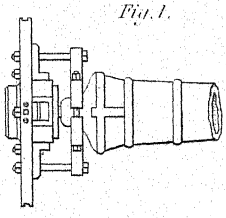
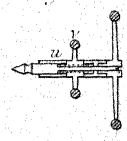


Fig. 5.



Taken from the 8th. Vol.
of Professional Papers.

J.W. Lowry fc.

London, John Weale, High Holborn. 1849.

BORING AND TURNING LATHE.

Fig. 1.

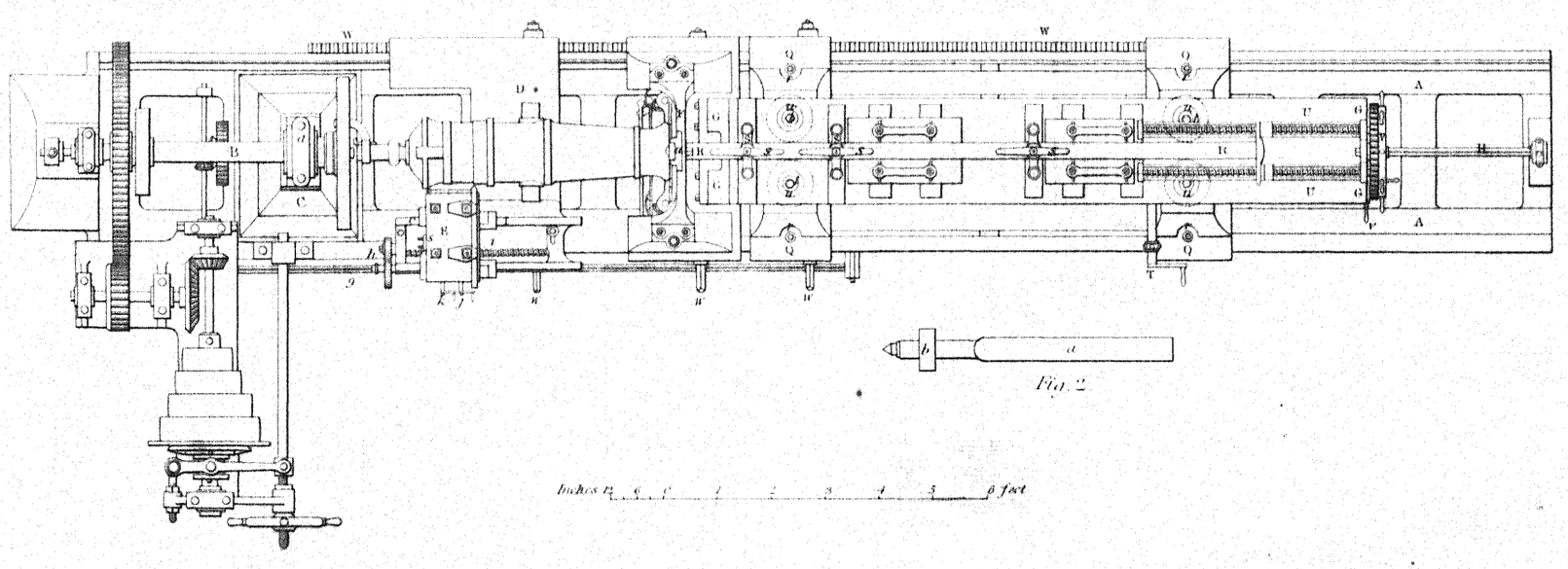


Fig. 2

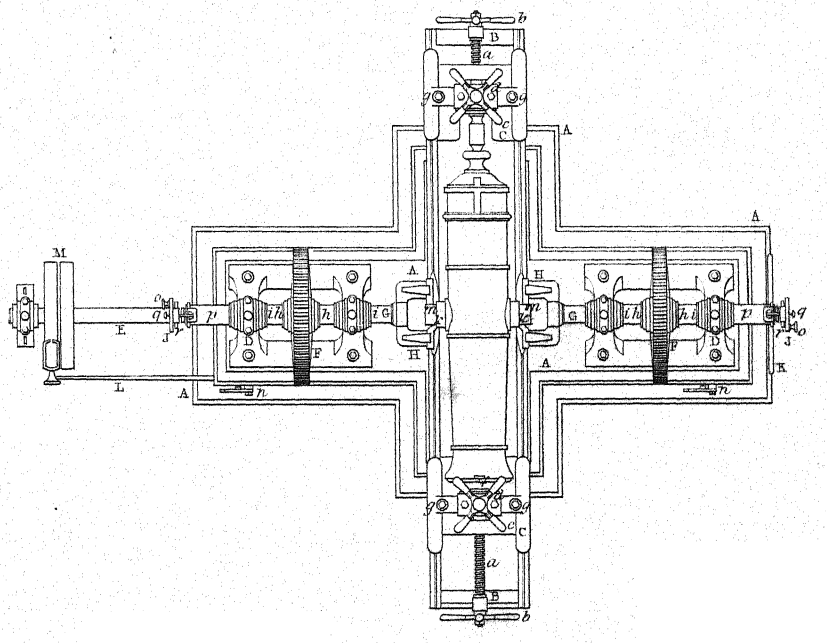
Taken from the 8th Vol. of Professional Papers

J.W.Lowry fc.

London, John Weale, 59 High Holborn, 184.



TRUNNIONING MACHINE

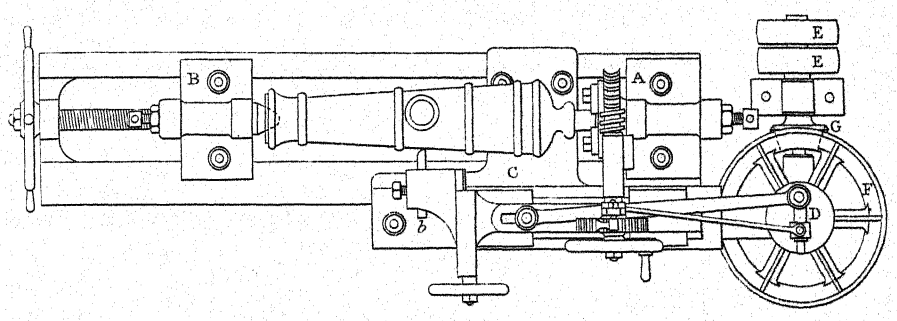


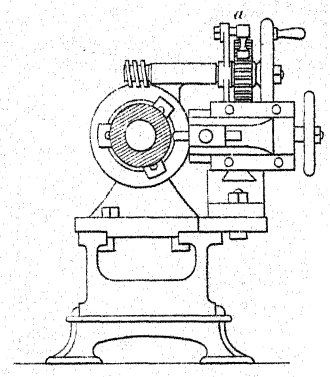
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I.W. Lowry fc.

London. John Weale 59 High Holborn 1849

PLANING MACHINE





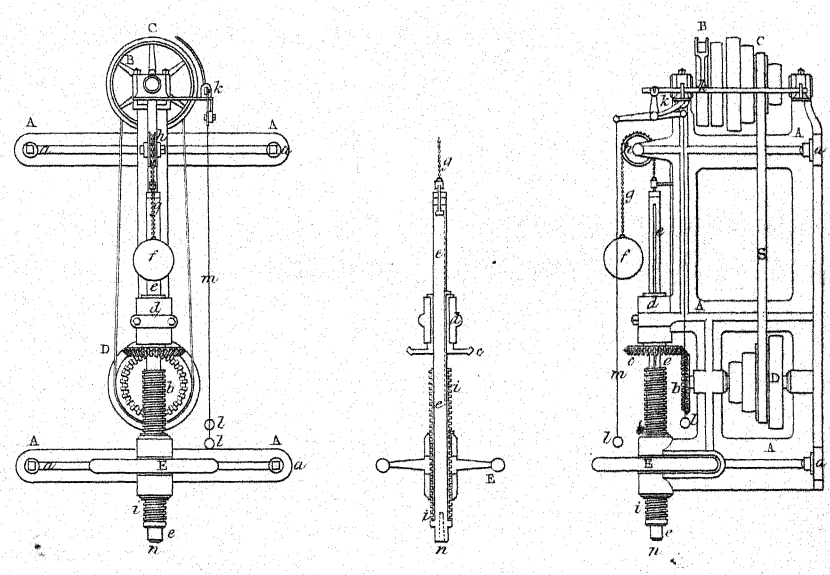
J. Anderson.

W. A. Beever, Jr.

London, Lockwood & Co. Stationers' Hall Court, E.C.



DRILLING MACHINE



Inches 12 9 6 3 0 1 2 3 4 5 feet

Taken from the 8th Vol of Professional Papers

J.W. Lowry fe.

BOUCHING FRAME.

Fig. 4.

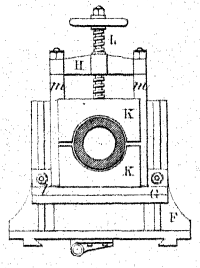


Fig. 3.

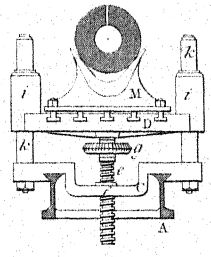


Fig. 2.

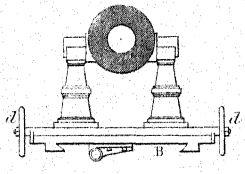
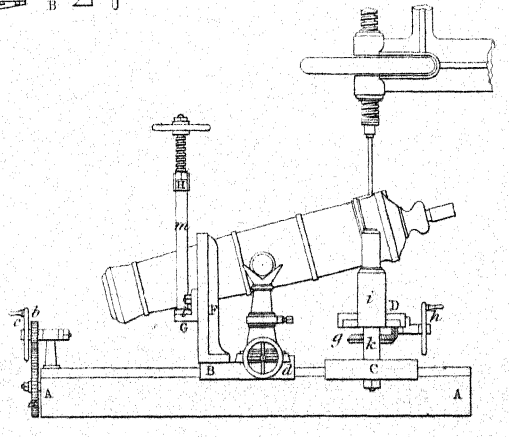


Fig. 1.



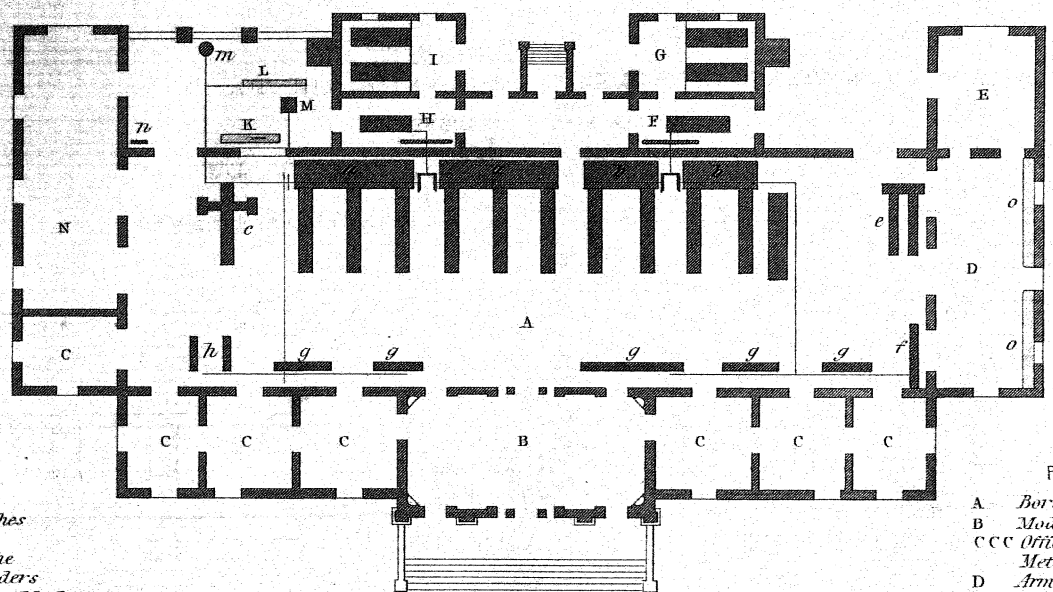
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London, John Weale, High Holborn, 1849.

G. Hutchinson F.R.S. Pl. of Bengal Engineers

Appendix —*Plate 6.*



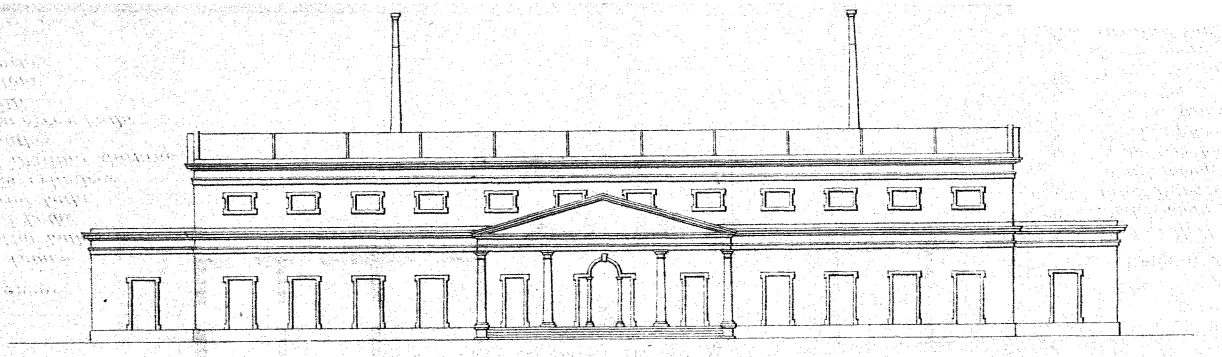
PLAN

References.

a a Six Gun Lathes
b b Four Mortar Lathes
c Trunnion Lathe
d Dead Head Lathe
e Lathes for Cylinders
f Vertical Drilling Machine
g g g Small Lathes
h Elevating Screw Lathe
m Loom Mill
n Grind Stone
o Vice Benches

References.

A Boring Hall
B Model Room
C C C Office, Pattern and Metal Rooms
D Armourers Room
E Finishing Room
F 12 Horse Steam Engine
G Boiler Room
H 10 Horse Steam Engine
I Boiler Room
K Circular Saw
L Cross Cut Saw
M Blowing Machine for Cupola for Casting Iron
N Carpenters Room



ELEVATION

25 20 15 10 5 0 25 50 75 100 125 150 175 200 feet

PLAN & ELEVATION OF THE FOUNDRY FOR BRASS ORDNANCE &c.

AT COSSIPORE NEAR CALCUTTA

ERECTED IN 1834 BY

LT COL: HUTCHINSON F.R.S. BENGAL ENGINEERS

SUPT & DIRECTOR OF THE FOUNDRY.

Published by John Weale, 59 High Holborn, 1849.

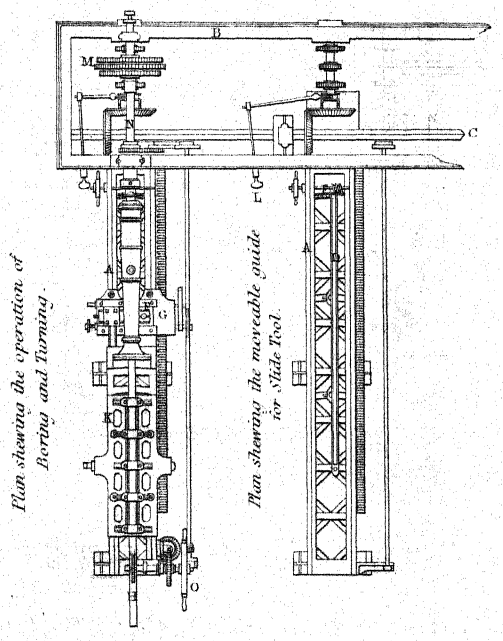
J.W. Lowry Sc.

Appendix 1.

Plan Section and Elevation of Lathe

on an entirely new Self Acting Principle

under the direction of Lt Col. G



REFERENCES

AAA *Boring Beds.*

B *Frame for carrying the Machinery for giving Motion to Mandrils.*

C *Shaft communicating with Steam Engine.*

D *Moveable Guide for Sliding Tool.*

E *Graduated Index for placing the moveable Guides at the required Angle.*

F *Slide attached to moveable Guide adapted to follow the taper of the Gun.*

G *Bed of Slide (F) with self traversing Motion adapted to moving parallel to the Axis of the Gun.*

H *Boring Bar; pressed forward by the Rack (I) moved by a pinion connected with the Self Acting Motion, or may be worked at pleasure by hand with the wheel O.*

I *Portion of Rack for propelling the Boring Bar other portions are fitted on at pleasure as the Bar enters the Gun.*

K *Carriage carrying the Boring Bar.*

L *Handle for throwing the Work in and out of Gear.*

M *Wheels for varying the speed of Mandrils (N).*

P *Reverse Motion to Bed (G) added after the Machinery was put up.*

S *Also a friction Clutch † was fixed upon the upright Shaft (S) giving motion to the pinion propelling the Boring Bar; also a friction Clutch was attached to the Mandrils. N N.*

W *The Box Chucks T, at the end of the Mandrils N, were altered for the face Plate W which greatly expedited the adjustment of the Gun.*

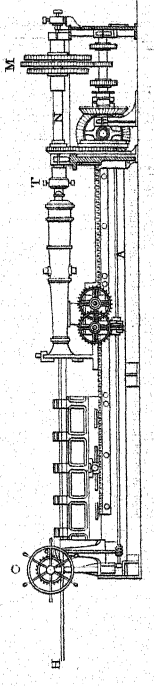
London, John Weale 59, High Holborn, 1850.

Construction of Ordnance.

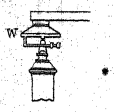
for Boring and Turning of Ordnance

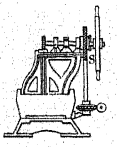
executed by Messrs. Hall and Sons, Dartford

Hutchinson F.R.S. Bengal Engineers.

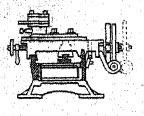


Elevation of Boring Lathe.





End View of Lathe —

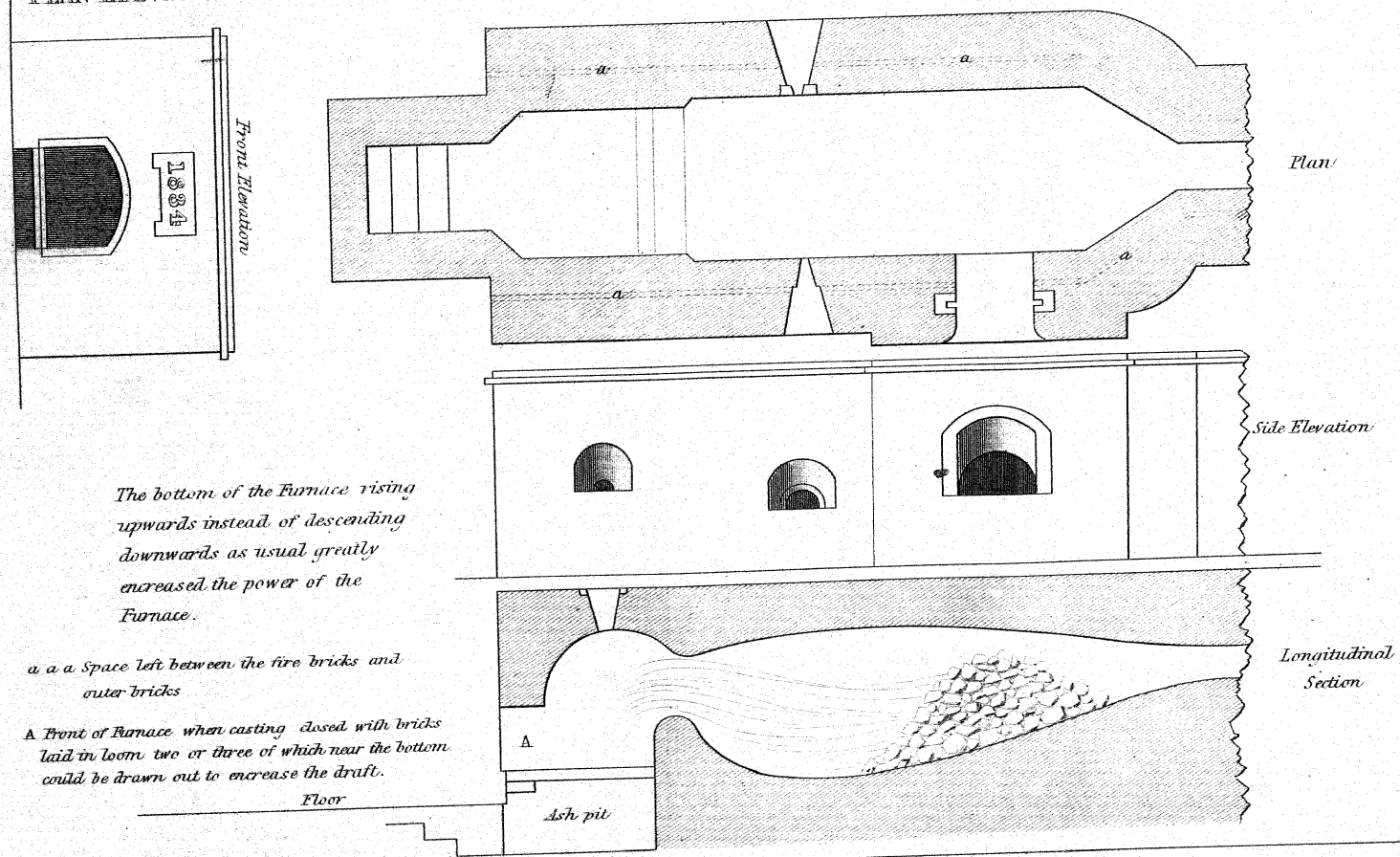


Section of Boring Bed
Slide Rest and Moveable Guide.

Inches 12 0 1 2 3 4 5 10 15 20 feet

83. The V collars with steel facings were abandoned and circular collars suited to each gun were found far preferable in diminishing the intensity of the heat generated by the friction.

PLAN ELEVATION & SECTION OF ONE OF THE REVERBERATORY FURNACES IN THE FOUNDRY AT COSSIPORE



The bottom of the Furnace rising upwards instead of descending downwards as usual greatly encreased the power of the Furnace.

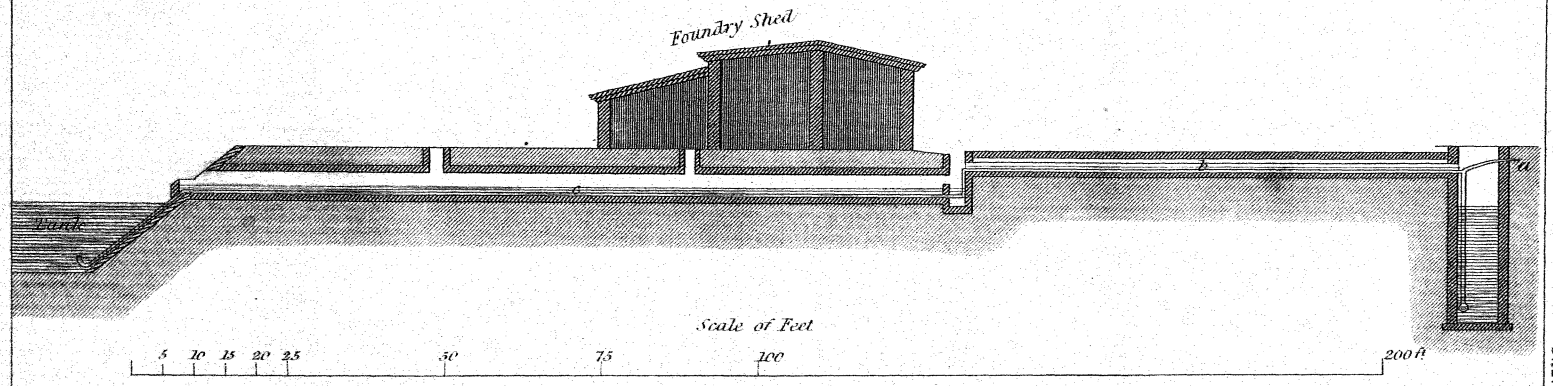
a a a Space left between the fire bricks and outer bricks

A *Front of Furnace when casting closed with bricks laid in loom two or three of which near the bottom could be drawn out to encrease the draft.*

Illustrations P.R.I. Civil Engineers.
Published by John Weale High Holborn 1849.
J.W. Lowry Sc.

Appendix *Ordnance, Construction of*

SYPHON LAID DOWN IN THE FOUNDRY YARD AT COSSIPORE.



Length of Syphon	*247 feet*	*a*	*Small pipe to the pump of the Engine*
Interior Diameter	*5 inches*	*c b*	*Syphon covered with Water*
Leg of Syphon in Wall	*22 feet*		

E. Hutchinson F.R.S.L. & of Bengal Engineers.

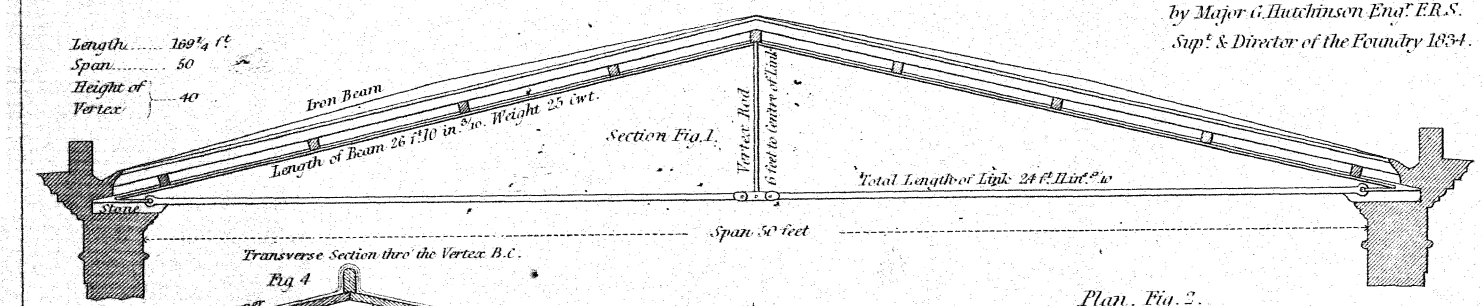
Published by John Weale High Holborn 1849.

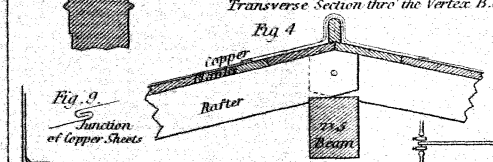
J. W. Lowry Sc.

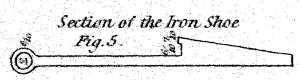
ORDNANCE. CONSTRUCTION OF. PLATE 10.

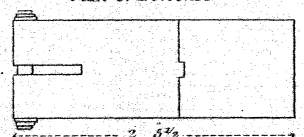
PLAN SECTION &c. OF THE LARGE IRON TRUSSED ROOF CONSTRUCTED OVER THE BORING ROOM OF THE NEW GUN FOUNDRY AT COSSIPORE

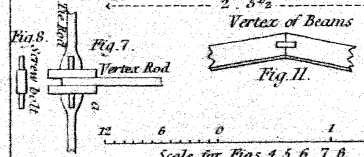
by Major G. Hutchinson Engr. F.R.S.
Supt. & Director of the Foundry 1834.

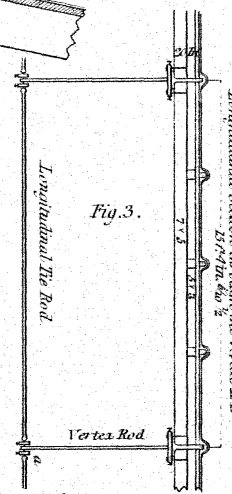


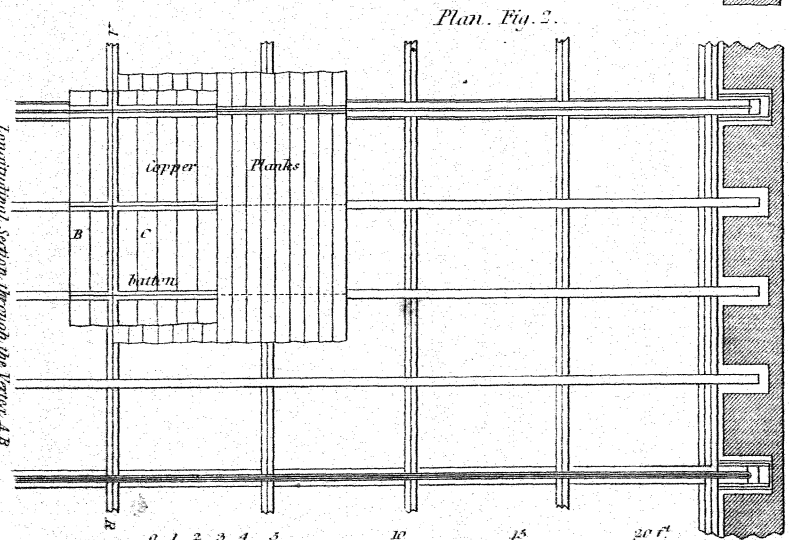












London, John Weale, High Holborn, 1850.

J. W. Lowry, fc.

ORDNANCE. CONSTRUCTION OF PLATE 11.



At the end of the 18th century, the Survey of Great Britain was placed under the direction of the Ordnance, and a corps of Surveyors and Draughtsmen formed, to assist in this operation; so that at the close of the War the duties of the Department had been increased from the mere provision, custody, and supply of warlike stores to the Sea and Land Service, to the construction and maintenance of fortifications, magazines, storehouses, and military buildings, in the United Kingdom and the Colonies, the entire government of the Royal Regiment of Artillery, the Corps of Royal Engineers and Sappers and Miners, the Survey of Great Britain, and the provision of ordnance, shot and shells, &c., for the Service of the East India Company.

When the War finally terminated in 1818, by the withdrawal of the army of occupation from France, and the Duke of Wellington became Master-General, his Grace's attention was directed to a reduction of the Ordnance Department, suited to the prospect of a long Peace, and the consolidation of others with it, which led to the amalgamation of the Barrack Department with the Ordnance, the extension of the Survey to Ireland, and the transfer of the store branch of the Commissariat (including the Quarter-Master-General's stores of camp equipage for the army in the field); and the Board of Ordnance was reduced to the following establishment:

The Master-General, *with a Military Secretary*,

With a *Civil Secretary*, { The Surveyor-General, / The Clerk of the Ordnance, / The Principal Storekeeper, } *Forming the Board*,

dividing the duties of the	Personnel,	under the	Master-General,
,,	Materiel,	,,	Principal Storekeeper,
,,	Finance,	,,	Clerk of the Ordnance,
,,	Audit of Expenditure of money and stores,	,,	Surveyor-General.

This Board is now entirely abolished as a separate Department, the Military Duties being carried on by the Commander-in-Chief; and the various civil branches by separate officers under the Secretary of State for War.

OVEN, FIELD.*—For camps or temporary purposes, an oven may be constructed of clay formed into an arch over a rough temporary frame or 'centre' of boards, and supported on a strong wooden or stone pier, so that the hearth may be about 3 feet above the ground, for convenience in putting in the bread; but by making an excavation in front for the same purpose, it may be placed on the level of the ground.

The floor or hearth should be formed of brick, stone, or clay tampered and well rammed.

Sun-burnt bricks or sods cut into the form of arch-stones may likewise be used for the upper part or roof; and if iron bars can be obtained, they may be used to support it; also logs or fascines well plastered with clay. A doorway is made in the front wall, and also an opening in the upper part of the farther end, for the smoke to escape by during the heating, both of which must be perfectly closed during the baking, when the temperature must be at least 250° Fahr. at the beginning, and 170° at the close. An oven should not be made to contain more than 500 rations, because it takes ten minutes to place that number in it; and more than ten minutes' difference of baking spoils the bread.

* By Lieut.-Colonel Bainbrigge, R.E.

For every 100 rations a superficies of hearth of 30 square feet is required, and the height inside should be about eighteen inches.

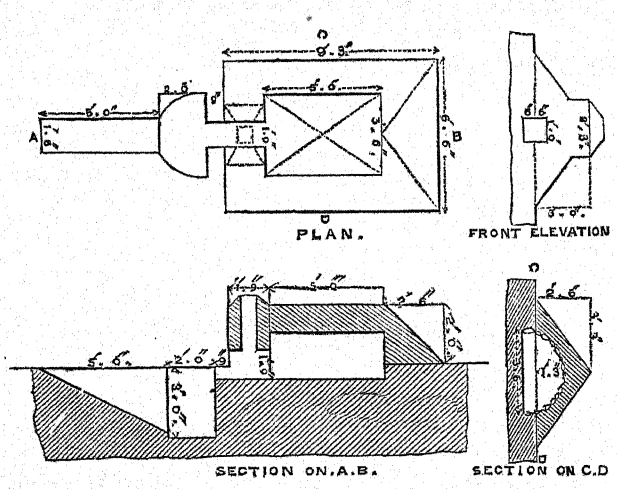
Travelling ovens of iron have sometimes been used, but the advantage of having the means of baking thus always at hand is considered to be more than counterbalanced by their requiring a great number of horses for their transport.

Kneading troughs are made by digging trenches in a dry spot, 2½ feet deep, for the bakers to kneel in; and parallel to them, with an interval of a foot, smaller trenches 1 foot deep, for the dough, having their sides levelled with planks, which should be dried by fires of chips; and the dough must be surrounded with dry branches, to insure its rising.

Another Mode.

The following method is adopted at Chatham, and is taken from observations made by Lieut. (now Major) Ewart, R.E., on the plans adopted in the Belgian Army.

A rectangular space 5 feet long by 3 feet 6 inches wide, is excavated to a depth of 6 inches for the hearth; it is carefully levelled and then covered with a mixture of clay and cow-dung, which is also applied to the sides and ends. At the proposed



entrance a sodwork flue is built up with a square aperture at bottom for a doorway, and a trench 3 feet deep is cut for the man serving the oven, with a ramp leading down from the ground level.

Meanwhile a segment having a chord of 3 feet 6 inches and a rise of 1 foot 3 inches, is laid out on the ground, and ten pickets, over 5 feet long, are driven round it, on which a brushwood hurdle is woven 5 feet high. The concave surface is covered over with clay and cowdung, and when dry washed over with a thin coat of the same. The arch when dry is laid over the hearth and then paid over with the like mixture and covered with earth. Such an oven would contain at one time 70 or 80 2 lb loaves, or bread enough for 140 to 160 men. The first time of heating would require from 1 hour to 1¼ hour.

To construct it, two men would prepare the hearth, flue, and end walls; two would get and mix the clay and dung with water, in the ratio of 3 to 1, and three men obtain brushwood and construct the arch; making a total of 1 N.C.O. and 7

men. As the first coat of clay must dry before putting on the second, the heat of the sun will determine the rate of completion.

DETAIL OF MEN AND TOOLS.

N. C. O.	Men.	Pickaxes.	Shovels.	Rammer.	Gabion Knives.	Bill-hook.	Mallet.	Tracing Line.
1	7	2	4	1	2	1	1	1

OVEN, PERMANENT.*

OVEN FOR 200 MEN, FORMERLY IN THE ROYAL SAPPERS AND MINERS' BARRACKS, WOOLWICH.

The oven shewn in the accompanying Plate requires half a bushel of coals to heat it sufficiently for all the ordinary purposes of baking for the soldiers' messes. The time necessary for this purpose is three hours. It is the practice to throw a small quantity of saw-dust into the oven, to hasten the process of heating it, and to burn away the small quantity of soot that accumulates on the top of the oven. (See Plate.)

The arrangement of the flues is explained by the dotted lines: that marked *a*, in the elevation, is the main flue, into which *b* is conducted, for the double purpose of creating a draught and carrying off the hot air and steam when drawing from the oven. (Fig. 2.)

Private Thomas Cliff, an experienced cook, in charge of the oven, suggested the suppression of damper *b*, seldom, if ever, used, reducing the throat of that flue at *d* (in section) to about 2 inches in depth, but extending the whole width of the oven door. (Figs. 2 and 3.)

He also suggested a flue from the furnace to run into the main flue, with a damper at C (in elevation): thus, by cutting off the fire in the furnace from the oven by a loose plate (*p*), and by opening the damper at C, the smoke, &c. would ascend by that flue; and it would be unnecessary to rake out the fire from the furnace for each baking, as is now the case. (Figs. 4 and 5.)

GRANT'S OVENS AND COOKING APPARATUS.

It would not be right to close this article without referring to Captain Grant's Cooking apparatus both for Field and Barrack service. The general principle of the latter will be understood by the following description of the apparatus erected in one of the cook-houses in the R.A. Barracks, Woolwich. The fires are lighted in grates at each end and the flues are carried nearly horizontally towards one another, till they reach the chimney-shaft, up which they are conveyed side by side, till they arrive at a convenient height, when they meet and form one flue to the top. In the shaft, and in contact with the flues, is a closet about 7 feet high and 2 feet 6 inches wide and deep, lined with iron, and fitted with racks for baking, a pan being placed at the bottom to catch the dripping. This is heated by the flues in contact with it, and if there is too much heat, a damper at the top of the oven and a little trap at the bottom of the door may both be opened, and thereby a draught of cool air made to pass through the oven.

* By Lieut. (now Captain) Ross, R.E.

There are also dampers where the flues meet the shaft for the purpose of shutting off one or other of them, if only one range of kettles is required, and another damper in the main shaft to regulate the general draught. The top of the flat portion, or stove, is covered with iron plates, in which holes are made to allow the kettles to sink for about 4 inches. The heat of the fire is so great that when the water is not otherwise wanted, it may be made to give off sufficient steam to cook vegetables &c., in four sets of steamers one above the other.

The following extracts are given from the report of the Committee appointed at Woolwich, to test the advantages claimed for this invention.

"The capabilities of the apparatus are equal to the requirements of 1000 men, and offer three of the most simple modes of cooking; that is to say, the oven will bake meat for considerably more than one-third of the above number; a portion of the kettles will stew meat and potatoes (usually called "Irish stew") for another third; and the remaining kettles will boil meat and soup for the rest. The potatoes are "steamed," a mode of cooking much superior to boiling.

"In addition to the foregoing, frying for 100 men may be carried on, and meat puddings or suet dumplings for 150 men can be boiled in the kettles under the potato steamers; both these modes of cooking are used daily, and much appreciated. These facilities, with the "hot plate" furnished by the horizontal cast iron surface of the apparatus, together form very important auxiliaries both in mode and extent to the three principal modes of cooking.

"The boiling water required for the breakfast and evening coffee meals is obtained with great facility.

"The oven is capable of baking meat for 400 men, and by a simple contrivance for allowing a current of cool air to pass from the bottom through the top, the meat is greatly preserved from the peculiar taste usually given by iron ovens, and has much the flavour of roasted meat.

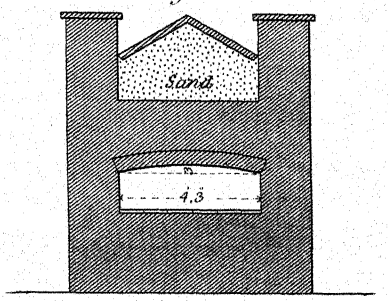
"The saving to the soldiers' messes in the sum paid for baking daily for 400 men (33 rooms of 12 men each), at 3*d.* per room (the charge made by the town baker at Woolwich), amounts to 2*l.* 17*s.* 9*d.* a week, or 150*l.* 1*s.* 3*d.* a year, a large sum paid by the soldier in following his taste for a baked dish in lieu of soup and boiled meat."

The average number of men cooked for on this occasion was 954 with 5½ cwt. of coal and 3lbs. of wood for lighting, or about 10½ ozs. per man per diem, but the apparatus would have cooked equally well without any increase of fuel for 1000 men, making an allowance of only 9·86 ozs. In the ordinary boilers for the same number of men, at the allowed rate of 90 lbs. of coal for 36 men, the daily consumption of fuel would be 2500 lbs. or 22 cwt. 36 lbs., a difference of 16 cwt. 92 lbs. per diem, or nearly 208 tons per annum in favour of Captain Grant. When this apparatus is used for smaller numbers under 500 men, the cost for fuel is somewhat greater. For 423 men the consumption was 4 cwt., or about 1½ lbs. per man per diem, but this seems to have been needless, for at Shorncliffe the average for 508 men was as follows :—

PER MAN PER DAY.						
Coffee.	Soup.	Boiled Meat.	Baked Meat.	Potatoes.	Tea.	Coal.
Pints.	Pints.	Ounces.	Ounces.	Pounds.	Pints.	Ounces.
1·688	·580	7·092	4·928	1·582	1·488	11·232

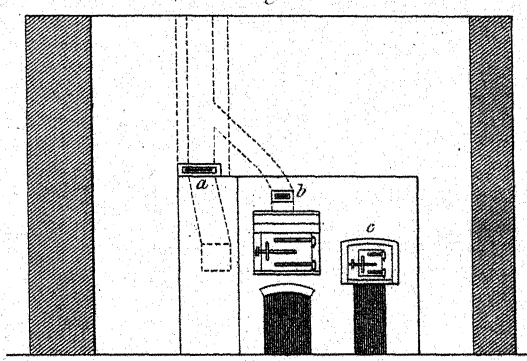
Oven for 200 Men
Royal Sappers & Miners Barracks
Woolwich.

Fig. 1.



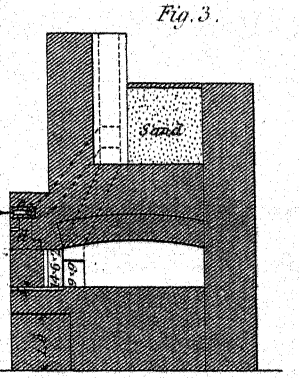
SECTION ON E.F.

Fig. 2.



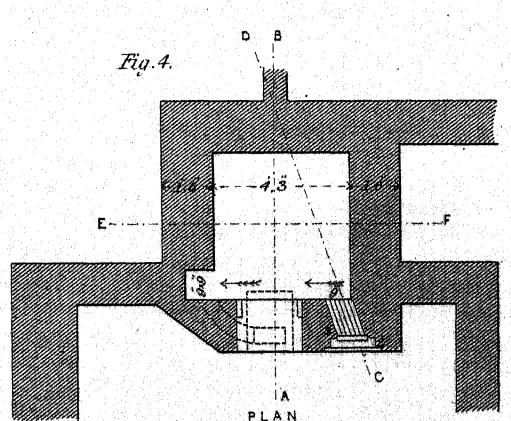
ELEVATION

Fig. 3.

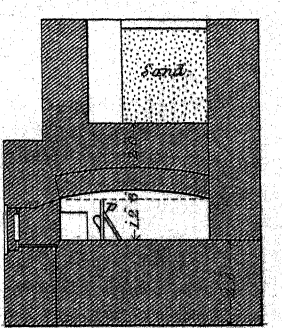


SECTION ON A.B.

Fig. 4.



PLAN



SECTION ON C.D.

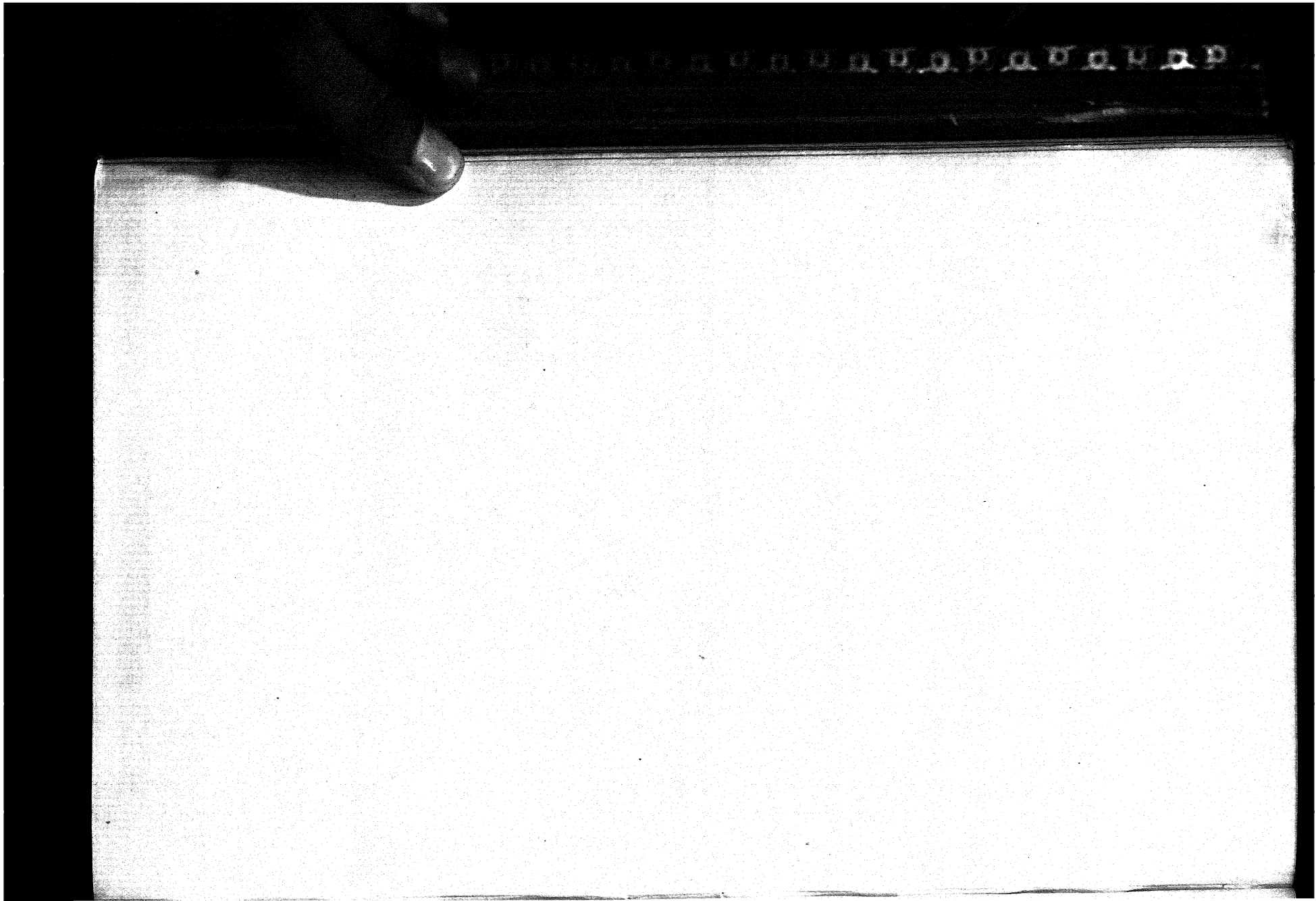
Fig. 5.

Scale of 3/16 of an Inch to 1 Foot.

12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 FEET.

T. Nugent 2nd Corpl R.S.& M. J.W. Lowry sc.

London, John Weale, 59, High Holborn, 1850.



The cost of such an apparatus for 500 men, but capable of cooking for 800, is about 90*l.**

Apparatus combining the above advantages has been made by Captain Grant in a more portable form for travelling, enough for 5000 men having been lately fitted by him to six artillery waggons for the Chinese expedition. He has also arranged another portable cooking apparatus, which may be used to carry troops across a river before or after cooking their dinner. The mode of using them is given in the following.

Instructions for the Management of Grant's Pontoon Cooking Kettles.

First select a level spot of ground, then cut the depth of the trenches equal to the diameter of the kettles, and the breadth one inch less, taking care to enlarge the openings where the fires are placed by splaying off the ground outside the kettles, at the ends of the trenches, at an angle of about 45°.

The kettles may be worked from a single kettle up to the full number of eight, in the form of a cross, and bear in mind that the cross is the most expeditious and the most economical way of managing the kettles for cooking: but as a less number will frequently be required, they may be worked in single lines, taking care never to cut the trenches in the direction of the wind, for although it may improve the draught of the windward fire, it will injure the draught of the leeward one. Therefore, as a general rule, it will always be better to cut the trenches at right angles with the wind, and when the full number of kettles are used, present one angle of the cross to windward.

When an iron chimney is not provided, a turf one may be substituted, about two or three feet high, taking care to keep the area of the flue equal to the square of the trench. Never place the fuel more than ten or twelve inches under the kettles except in wet or boisterous weather, and the exterior diameter of the kettles should always be kept on a level with the ground in order that one half of the kettle may drop into the trench, and be exposed to the direct action of the fire.

It frequently happens that sufficient attention is not paid to the cutting of the trenches, and the hurry to get the fires lit as soon as possible, is often the cause of their being cut in an irregular and slovenly manner; when this is the case there will always be a difficulty for the want of proper draught in keeping up good fires, and consequently a great delay in the cooking.

In marking out the line of trenches, do not cut them the full width at first, for a little earth from the edges is easily removed, to bring the kettles to a level and proper bearing. But if they are cut too wide the kettles will drop too low in the trenches, and cause much trouble to rectify. The provision for steaming and frying, is intended to be carried on immediately over the fires at the ends of the trenches, and is so simple that it requires no further direction.

N.B.—If these instructions are properly carried out, all the fires lit at the same time, and well regulated, the dinners for 800 men may be cooked in an hour and half, when the full complement of kettles is used in the form of a cross.

C. R. B.

PAH. †—The strength of the Pahs of New Zealand consists principally in the choice of position.

They are generally situated on peninsular points, with three sides inaccessible,

* The ironwork is manufactured by Mr. Kennard, 67, Upper Thames Street, and Mr. Spillar, 14, York Street, Blackfriars Road—where patterns may be seen.

† By the late Captain Bennett, R.E.

being steeply scarped towards the sea, usually from 50 to 60 feet in height, and palisaded at top; the depth of water round them is such as to prevent any vessel larger than those of 6 or 8 tons burden approaching them within the range of field guns. The attack of three sides, except by surprise, is therefore impracticable; and the fourth side is always cut off by a deep ditch having steep scarps from 20 to 30 feet in height, and counterscarps from 6 to 16 feet. The nature of the soil, being generally a stiff clay or soft sandstone, retains the slope of 60 degrees.

The terreplein, from 20 to 30 feet broad, has a strong palisade in front, as shewn in Plate II., or upon the parapet and banquette, as in Plate I., fig. 2; and the whole of the interior of the pah is intersected in every direction by fences: the ditches are frequently flanked by a strong palisade. In addition to the principal pah, there is also frequently an outer work with a low ditch palisaded in front, and commanded by the main work (Plate III., figs. 5 and 10); and should one part of the pah be considered weaker than another, it is strengthened by a double palisade 2 feet wide (fig. 9), with embrasures, and a trench to afford cover. Pahs are sometimes strengthened by three rows of palisades, as shewn in section, fig. 13, Plate IV.

The palisades themselves consist of large trees about one foot in diameter, roughly hewn; they are from 12 to 20 feet in height, rudely ornamented at top: between these, long stakes from 8 to 10 feet high, and 1½ inch in diameter, and tangent to each other, are strongly bound together, as in figs. 6, 7, and 8, and sometimes rough three-sided stakes, about 9 inches in diameter, are used.

Should the pah not be situated on a peninsula, its front consists of one steep side towards the sea, with generally a deep and wide gully on each flank, and the gorge is protected by a deep ditch, as before described.

The sections of the Pahs of Motua, Tapû, Otumaiti, and Tamutu, will be sufficient to exemplify the usual defences, but the natives of New Zealand evince considerable military knowledge.

The number of men the pahs could contain varies from 300 to 800, and they contain a large supply of provisions in holes excavated for the purpose: the men are well armed with muskets, and well supplied with ammunition, and they use the tomahawk for close quarters.

The choice of position relates to that arm against which they have hitherto had to contend, viz. the musket: and as they are generally commanded at points from 200 to 600 yards distant, they are open to destruction from light shells and carcases; but without artillery the attack of a strong pah may be attended with considerable loss to the assailant.

Note.—Description of Heki's Pah, in New Zealand, by Major Marlow, Royal Engineers, Plate IV.

The dotted lines denote rows of fences composed of trees deeply sunk in the ground, between 9 and 15 inches thick, bound close together by a strong native line or rope at the top and bottom: upon the outer row of trees a screen between 4 and 6 inches thick, and 8 and 9 feet high, was formed from a native plant called the New Zealand flax, which is exceedingly tough, and at a distance capable of resisting a musket-ball.

This screen was kept about 18 inches above the ground, to serve as loop-holes to fire through from the trench marked T T, Plate IV., figs. 13 and 14; S S serving as traverses.

Explanation

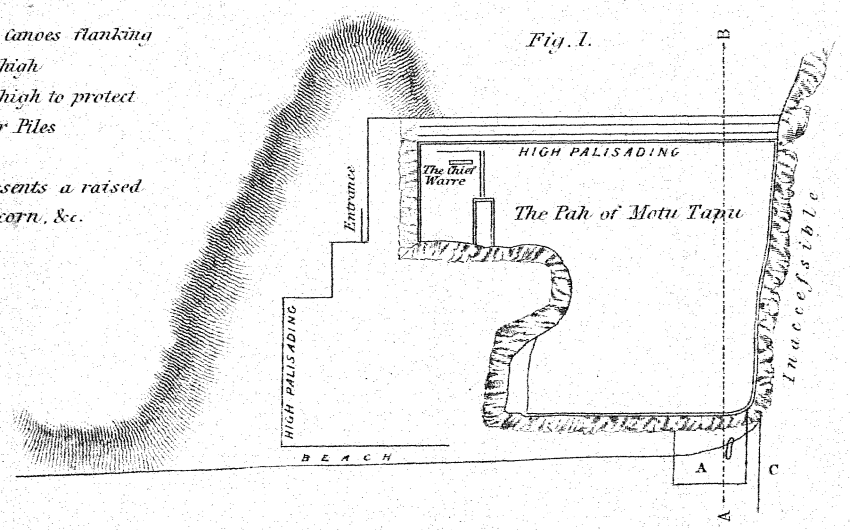
A *A Palisade enclosure for Canoes flanking the landing Place 20 feet high*

C *Strong Palisades 15 feet high to protect the enclosure A Fender Piles*

D *An Entrance or Ramp*

⇧ *In the Section this represents a raised shed for keeping fish, corn, &c.*

Fig. 1.



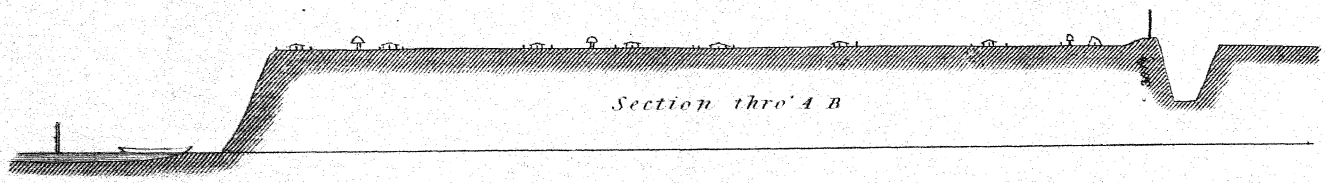


Fig. 2.

London, John Weale, 59 High Holborn, 1850.

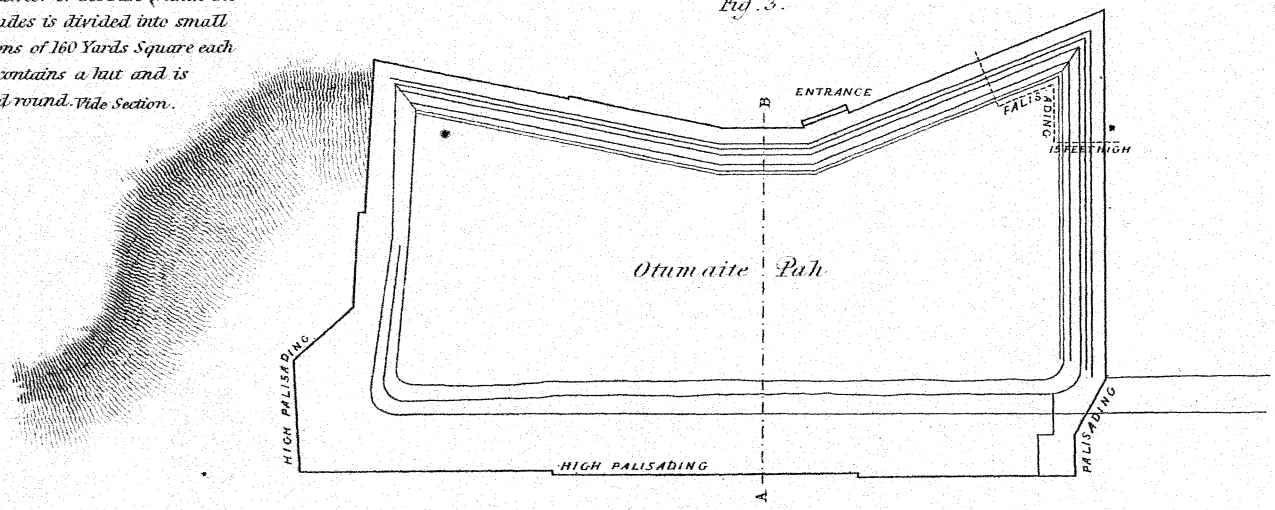
J. W. Lowry, fc.

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Explanation

The interior of the Pah within the Palisades is divided into small Portions of 160 Yards Square each part contains a hut and is fenced round. Vide Section.

Fig. 3.



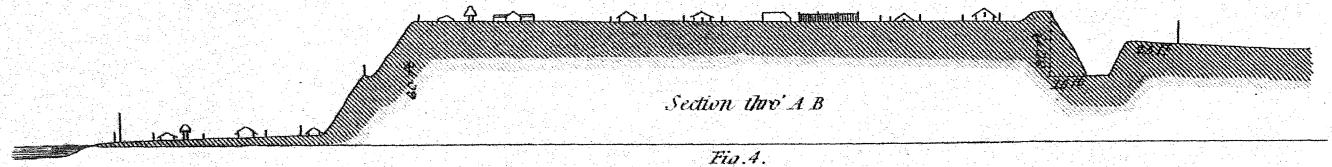


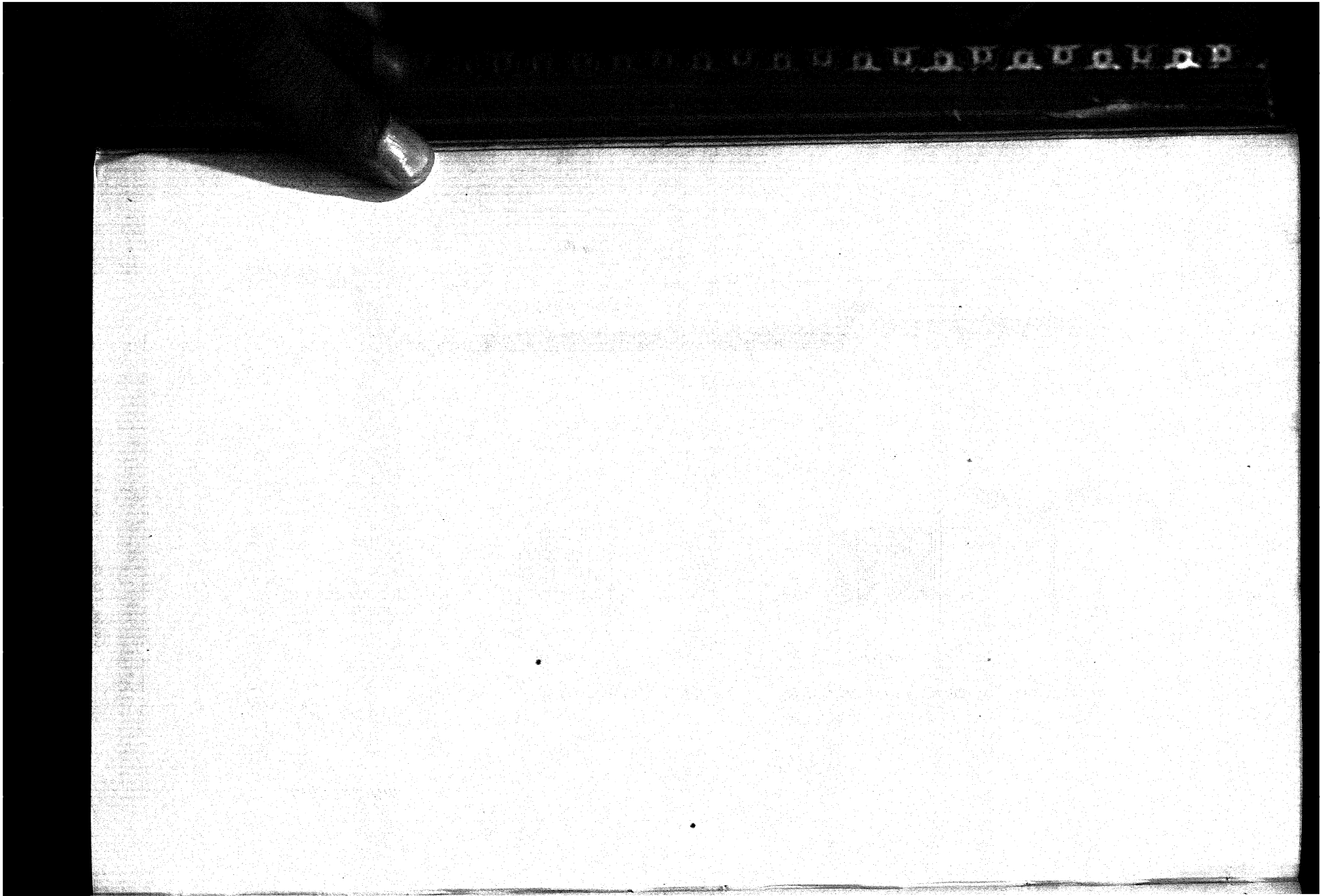
Fig. 4.

30, 5, 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 feet for Sections
Yards for Plans

London, John Weale 59 High Holborn 1850.

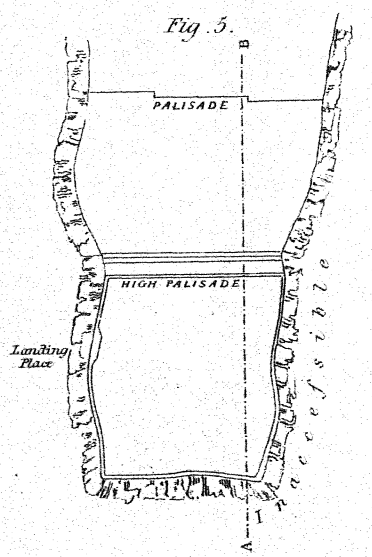
J. W. Lowry, Sc.

PAH. PLATE 2.



Tamutu's Pah

Fig. 5.



Common Palisades

Fig. 6.

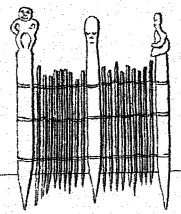
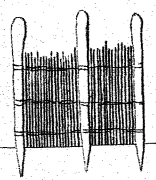
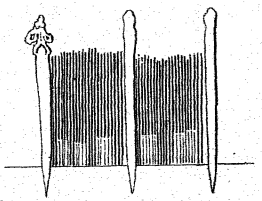


Fig. 7.



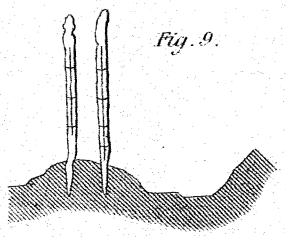
Double Embrasured Palisade

Fig. 8.

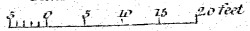


Section of same

Fig. 9.



Scale for Palisades



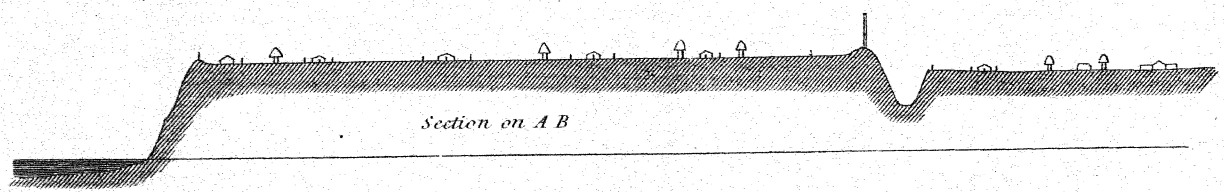


Fig. 10.

PAH. PLATE 3.

Plan of Heki's Camp and Pah

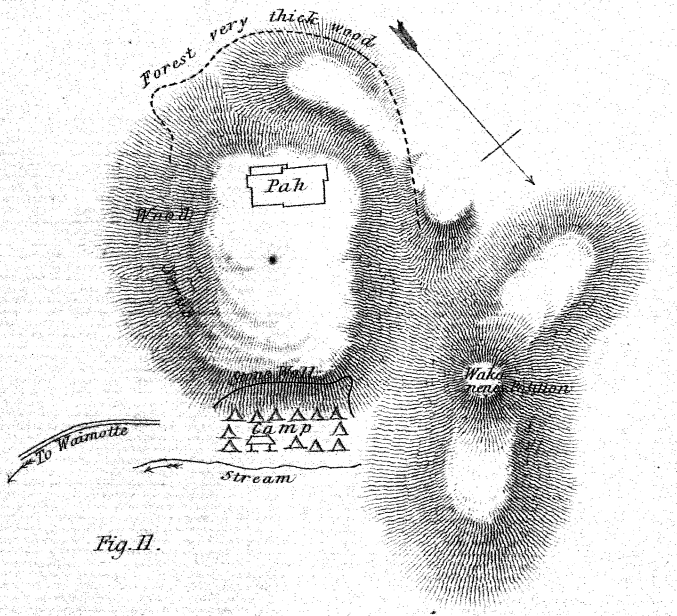
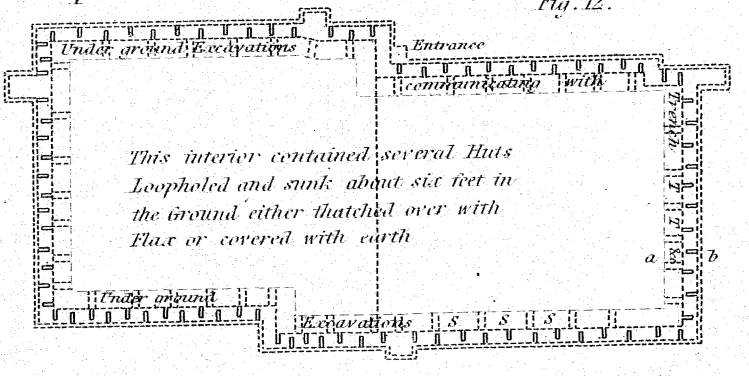
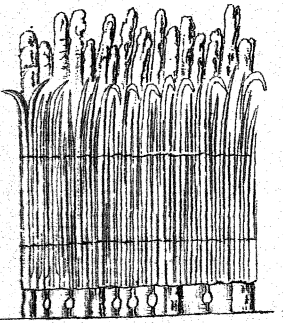


Fig. II.

Fig. 12.





Elevation of Part of the outer Fence of Pah shewing the Flax Screen and Loopholes in the second Fence

Fig. 14.

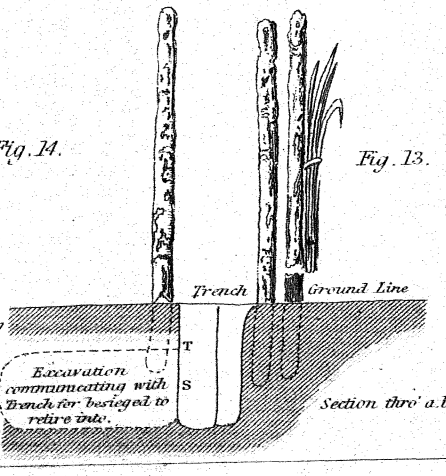


Fig. 13.

Scale of Yards.

200 50 0 100 200 300 400 500 Yards

Scale to Plan Fig. 12.

10 5 0 10 20 30 40 50 60 70 80 90 100 200 feet

Scale to Elevation and Section

0 1 2 3 4 5 6 7 8 9 10 20 feet

PAH, PLATE 4.

of Lieut T.M.J.

PALANQUES.—According to Bousmard, Palanques were small intrenched camps, used by the Turks in their irruptions into Europe, to secure their conquests, and as strongholds for their families and plunder, and were capable of containing a garrison of from 700 to 4000 men.

The construction of these forts or fortified posts was generally of timber, of a rude nature, similar to the *pah* of the New Zealanders.*

* "Les hyppas sont des enceintes de troncs d'arbres jointifs, plantés avec quelque inclinaison vers l'intérieur de l'espace renfermé; en sorte que les défenseurs placés sur des plateformes, ou échafauds élévés intérieurement, de distance en distance, et surtout aux angles de l'enceinte, découvrent parfaitement à l'extérieur le pied de ces troncs d'arbres."—*Essai Général des Fortifications. Discours Préliminaire.*

END OF VOL. II.

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